TABLES

DIMENSIONS AND CAPACITIES OF PLANNED HAZARDOUS WASTE STORAGE TANKS

Planned future permitted storage tanks are listed by containment dike location.

(M = 1,000 gal., C/S = carbon steel, S/S = stainless steel)

DIKE DESIGNATION	MAT'L OF CONST.	TYPE OF BTM.	APPROX. TANK SIZE DIA.-HT,ft.	APPROX. OVERALL HEIGHT,ft.	NO. OF TKS.	WORKING TANK CAP. (M gal.)	CAPACITY PER SIZE (M gal.)
Existing HW Tank Dike	CS	FLAT	13 - 25.2	26	5	25	125
(With Planned Tanks)	S/S	FLAT	12 - 24.8	25	2	21	42
Total Permitted Capacity, M gal.							167
Existing Feed & Bottoms Dike	CS	CONE	8 - 20	23	2	6	12
	CS	CONE	10.5 - 27	32	1	16	16
Total Permitted Capacity, M gal.							28
Rail Dike R-1	CS	FLAT	12 - 29.6	30	3	25	75
	CS	CONE	12 - 20	24	1	15	15
Total Permitted Capacity, M gal.							90
Tank Farm Dike B-4	CS	FLAT	12 - 29.6	30	2	25	50
	CS	DISH	12- 19	23	5	15	75
	CS	CONE	12 - 20	24	2	15	30
Total Permitted Capacity, M gal.							155
HW Fuels Dike F-1	CS	DISH	9.5 -		1	9.5	9.5
	CS	CONE	10 - 15	26.5	1	10	10
Total Permitted Capacity, M gal.							19.5
HW Fuels Dike F-2 (W. Sect.)	CS	DISH	12 - 19	23	4	15	60
East Warehouse Dike	S/S	SLOPE	4x6x7 Rect	10	2	1	2
	CS	CONE	4 - 7	10	2	0.75	1.5
							3.5
HW Solv. Cont. Proc. Bldg.	CS	SLOPE	4x6x7 Rect	10	2	1	2
Corrosive HW Proc. Bldg.	S/S	DISH	8 - 10.5	12	3	4	12
Spent Acid Tank in Dike	CS	HORIZ	11 - 20LG	13	1	12	12
TOTAL CAP. OF PLANNED PERMITTED HAZARDOUS WASTE TANKS FOR SITE, M gal.							549

Hazardous Waste Storage Tank Dikes - Containment Summary for Current Dikes

Calculated by taking the internal dike volume and subtracting the volumes of the pedestals and all but the largest tank from base to top of wall. Cone and Dish bottom tanks have no displacement within the dike. All outdoor dikes designed to contain the largest tank's contents plus four inches of rainfall minimum per OAC 3745-55-93(E)(1)(b).

Refer to Appendix D of each tank system's Exhibit for details of calculations.

	<----------		DIKE DESIGNATION			---------->
ITEM	7-TANK	FEED & BTMS. **	F-1	4x3M Gal. Feed Tk.	E. WHS. for DISPERSER	SPENT ACID
No. of Tanks in Dike	9	4	4	4	3	5
Largest Tank in Dike - Vol., gal.	21,000	16,000	15,000	2,900	2,000	12,000
Height of Dike Wall, ft.	3.00	3.8 & 2.6	3.17	1.50	0.38	2.67
Area of Dike, sq.ft.	2,970	615	918	275	6,424	1,265
Vol. , Top of Wall to Slab, cu.ft.	8,910	1,924	2,907	413	450	3,374
Volume of Pedestals, cu.ft.	568	N/A	95	N/A	See Below ***	109
Volume of Any Raised Concrete Slab, cu.ft.	663	N/A				
Volume of all but Largest Tank Below Top of Wall, cu.ft.	1,340	N/A				594
Net Volume for Containment, cu.ft.	6,339	1,924	2,812	413	450	2,671
Volume of 4 inches Rainfall, cu.ft. *	1,081	256	359	N/A	N/A	481
Capacity of Largest Tank, cu.ft.	2,807	2,139	2,005	388	267	1,604
Required Containment, cu.ft.	3,888	2,395	2,364	388	267	2,085
Cont. OVER Req'd Amt., cu.ft.	2,451	1,979	448	25	183	586
Exhibit where Details for Calculations are Found.	**Exhibit D-2**	**Exhibit D-10**	**Exhibit D-6**	**Exhibit D-7**	**Exhibit D-8**	**Exhibit D-9**

* Rainfall Area Includes the Top-of Wall Aera.

** Feed & Btms. Tank dike wall was notched at top of common wall to Exist. 7-Tank Dike to get required containment. Refer to text under "Spill Containment Volume for Dikes" in Section D for discussion and Appendix B of Exhibit D-10.

*** Used only aisle space to demonstrate more than required containment available.

CONTAINMENT CALCULATIONS FOR H.W. CONTAINER STORAGE AREAS AND UNLOADING DOCK AREAS.

Calculations take the internal containment area by the minimum curbing height for the maximum containment volume. The added volumes due to floor slope and trench volume are also included. Then, the displacement for pallets or other major displacements are subtracted from the total volume to get the Net Containment Volume available with the maximum permitted storage on hand.

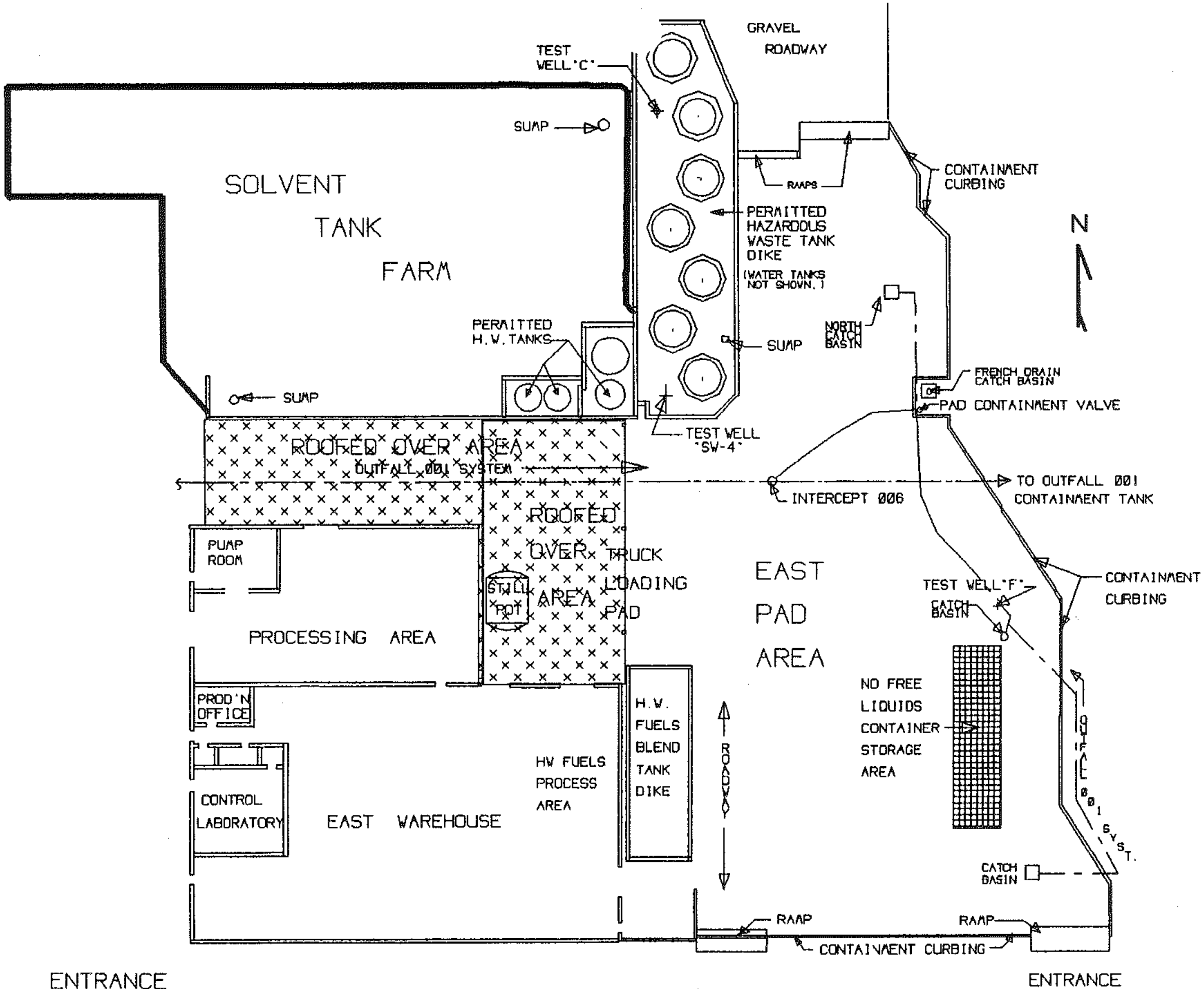
Truck Unloading Dock Areas are designed to contain 44,000 pounds of the Hazardous Waste normally unloaded at that dock. Volume is based on density.

The volume of a typical pallet was calculated as 1.9 cubic feet. However, for containment calculations, only the portion of the pallet below the top of the minimum height of the containment wall is considered.

ITEM	EAST WAREHOUSE	PROCESS BUILDING	PLANNED CONTAINER PROCESS BUILDING	PLANNED CORROSIVE CONTAINER BUILDING	PLANNED SPENT SOLV. UNLOADING DOCK AREA	PLANNED CORROSIVE UNLOADING DOCK AREA
Length Inside Containment Area, ft.	92	80	119.33	72	60	24
Width Inside Containment Area, ft.	74	44	98	48	50	23.5
Height of Containment Area Curb, ft.	0.375	0.375	0.333	0.333	2.4	1.167
Containment Volume, cu.ft.	2,553	1,320	3,894	1,151	7,200	658
Reduced by Dikes, Other Items, cu.ft.	---	334	661	---	---	---
Added Volume Due to Slope, cu.ft.	N/A	N/A	1,282	288	900	469
Total Possible Containment Vol., cu.ft.	2,553	986	4,515	1,439	8,100	1,127
Maximum Number of Drums for Area	916	100	1500	500	N/A	N/A
Number of Pallets on Floor, * (55 gal. dms.)	114.5	25	187.5	62.5	N/A	N/A
Max. Number of Gallons for Bulk Truck, gal.	N/A	N/A	N/A	N/A	6,600	5,300
Volume of Pallets to Curb Min. Height, cu.ft.	99	21	135	45	---	---
Net Volume for Containment, cu.ft.	2,454	966	4,380	1,394	7,200	1,127
Converted to Gallons Containment Vol., gal.	18,360	7,224	32,765	10,426	53,863	8,432
Largest Haz. Waste Volume Available, gal.	50,380	5,500	82,500	27,500	6,600	5,300
Ten Percent Containment for Drums, gal.	5,038	550	8,250	2,750	N/A	N/A
Add 4" Rain Volume for Outside Areas, gal.	N/A	N/A	N/A	N/A	7,474	2,810
Required Containment Volume, gal.	5,038	550	8,250	2,750	14,074	8,110
Containment OVER Required Amount, gal.	13,322	6,674	24,515	7,676	47,263	322

* Pallets are normally stacked two high. This means that eight drums occupy a single pallet area. Exception is the Processing Area, ONE pallet high.

Attachment A

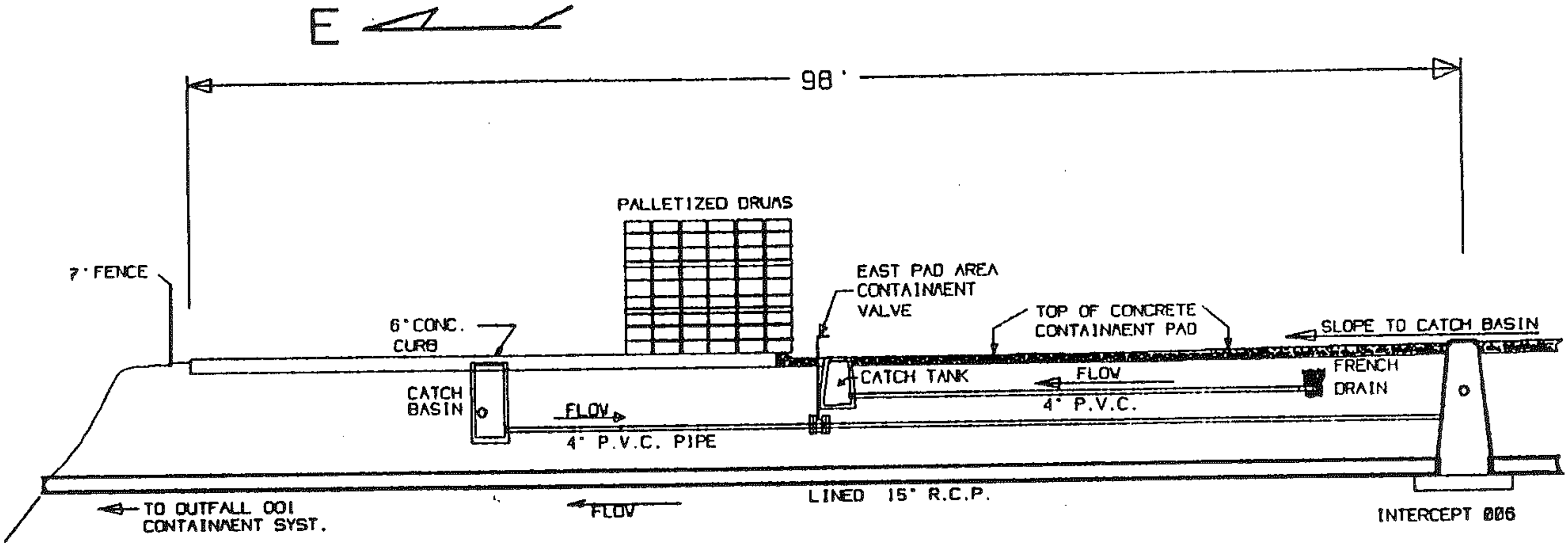


PLAN SHEET 8

EAST PAD AREA

HUKILL CHEMICAL CORPORATION

\PARTB-9\PLNSHT8.GCD Rev. 4/4/95



HUKILL CHEMICAL CORPORATION

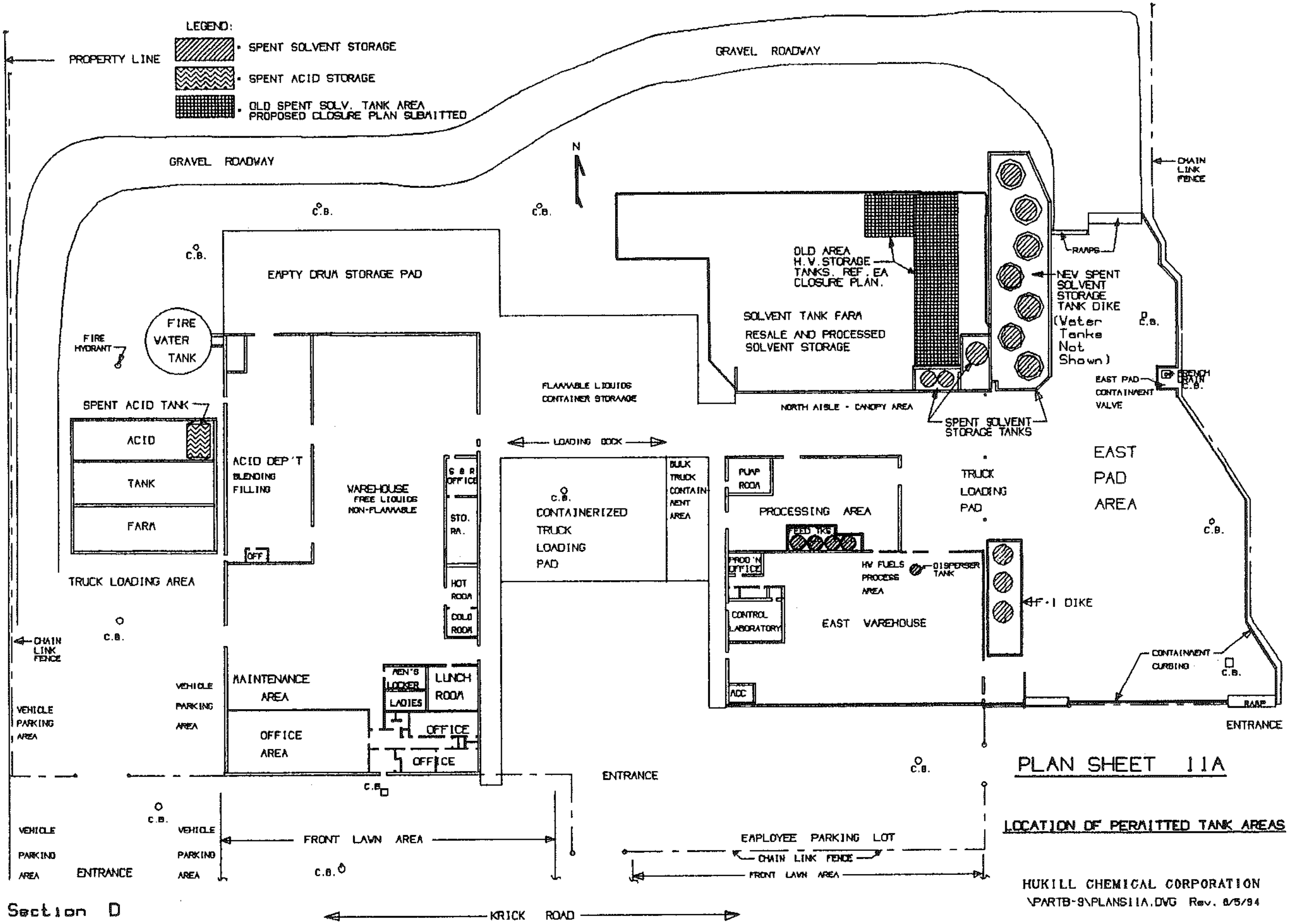
\PARTB\SECCONT.DWG Rev. 8/9/90

PROFILE OF NO-FREE-LIQUIDS CONTAINER STORAGE AREA AND EAST CONTAINMENT PAD

PLAN SHEET 9

Hukill Chemical Corp.

Revision 9, 8/94



PLAN SHEET 11A

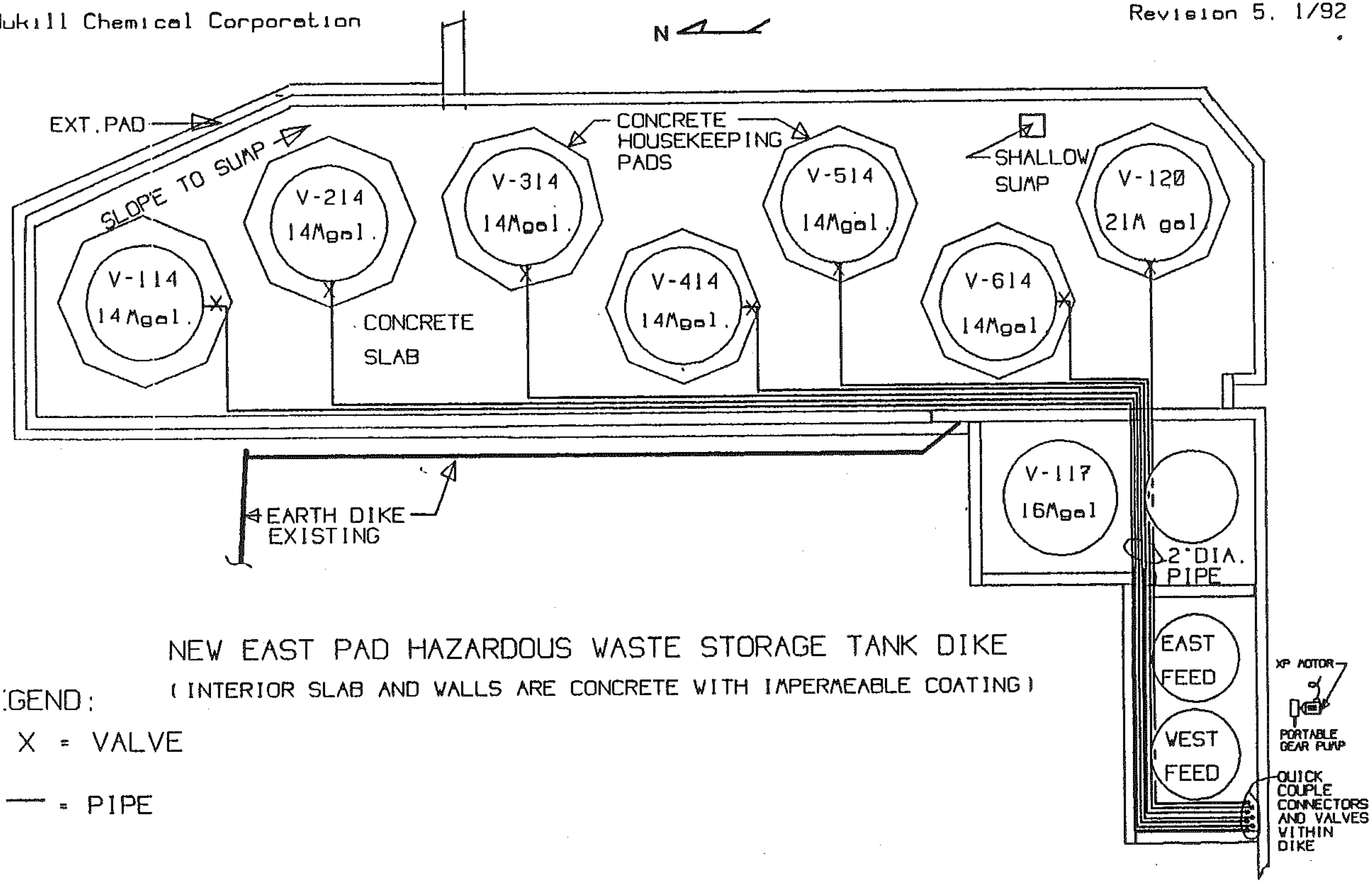
LOCATION OF PERMITTED TANK AREAS

HUKILL CHEMICAL CORPORATION
\PARTB-9\PLANS11A.DWG Rev. 8/5/94

Section D

Hukill Chemical Corporation

Revision 5, 1/92



NEW EAST PAD HAZARDOUS WASTE STORAGE TANK DIKE

(INTERIOR SLAB AND WALLS ARE CONCRETE WITH IMPERMEABLE COATING)

LEGEND:

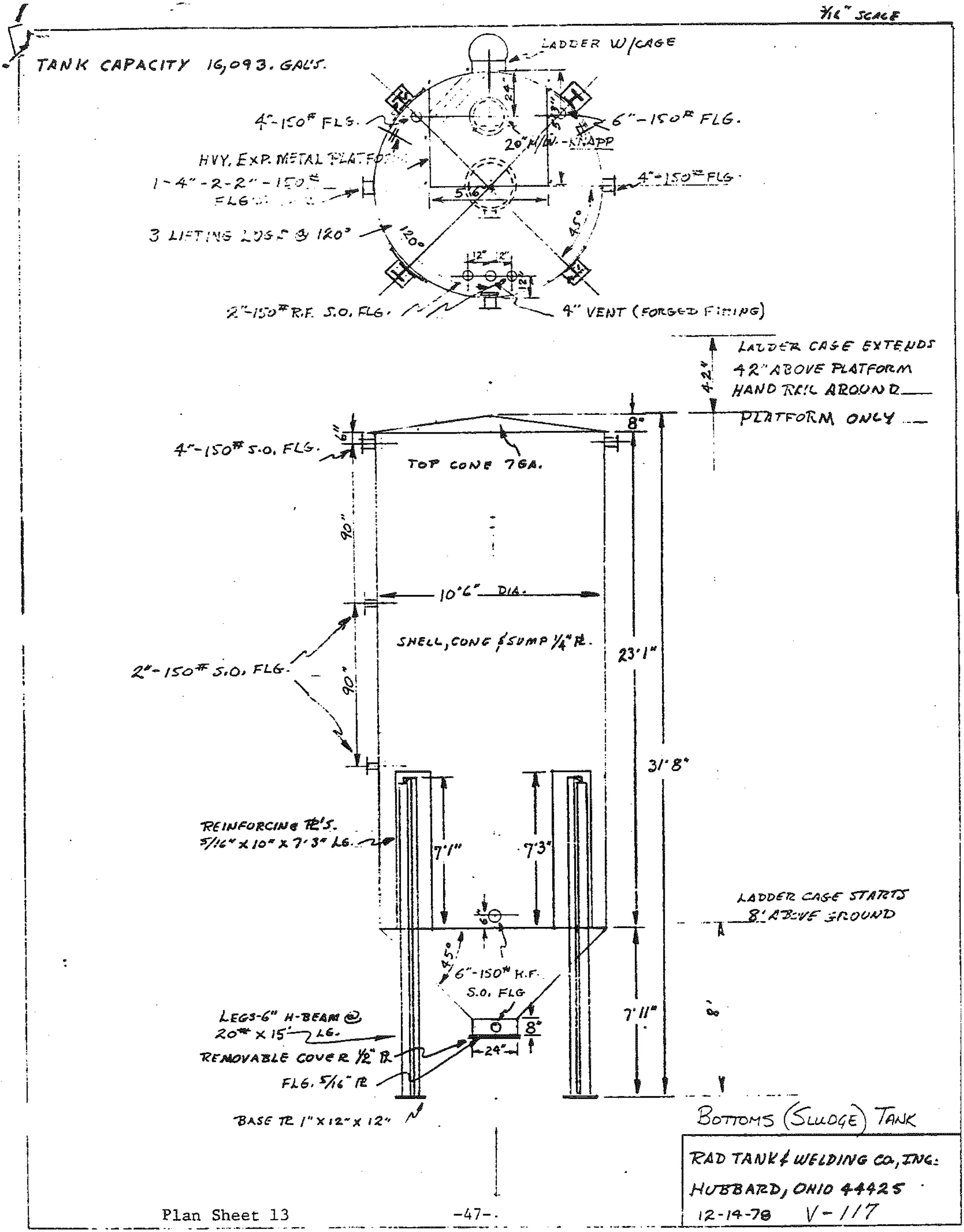
X = VALVE

— = PIPE

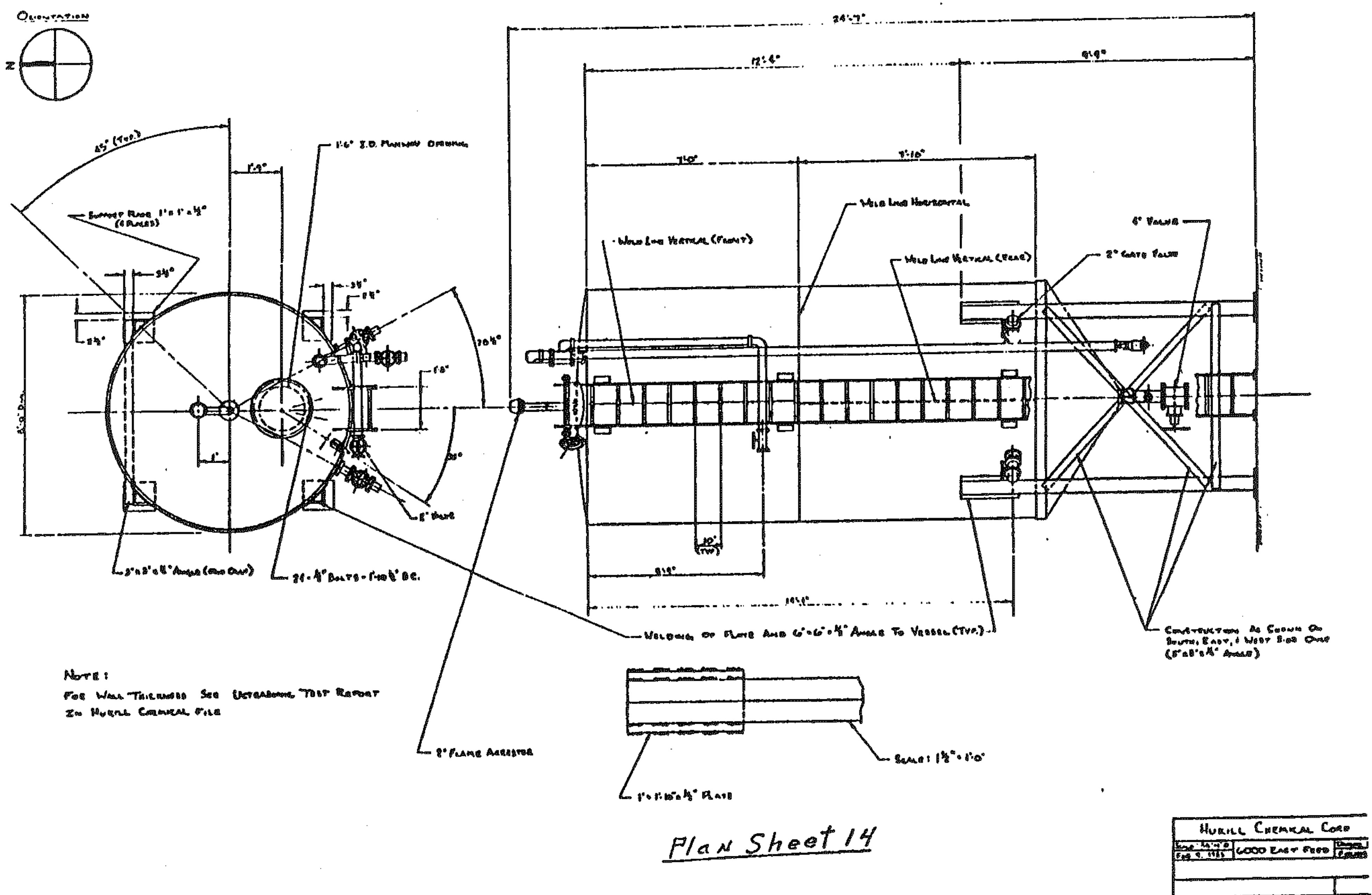
Plan Sheet 11B

HUKILL CHEMICAL CORPORATION

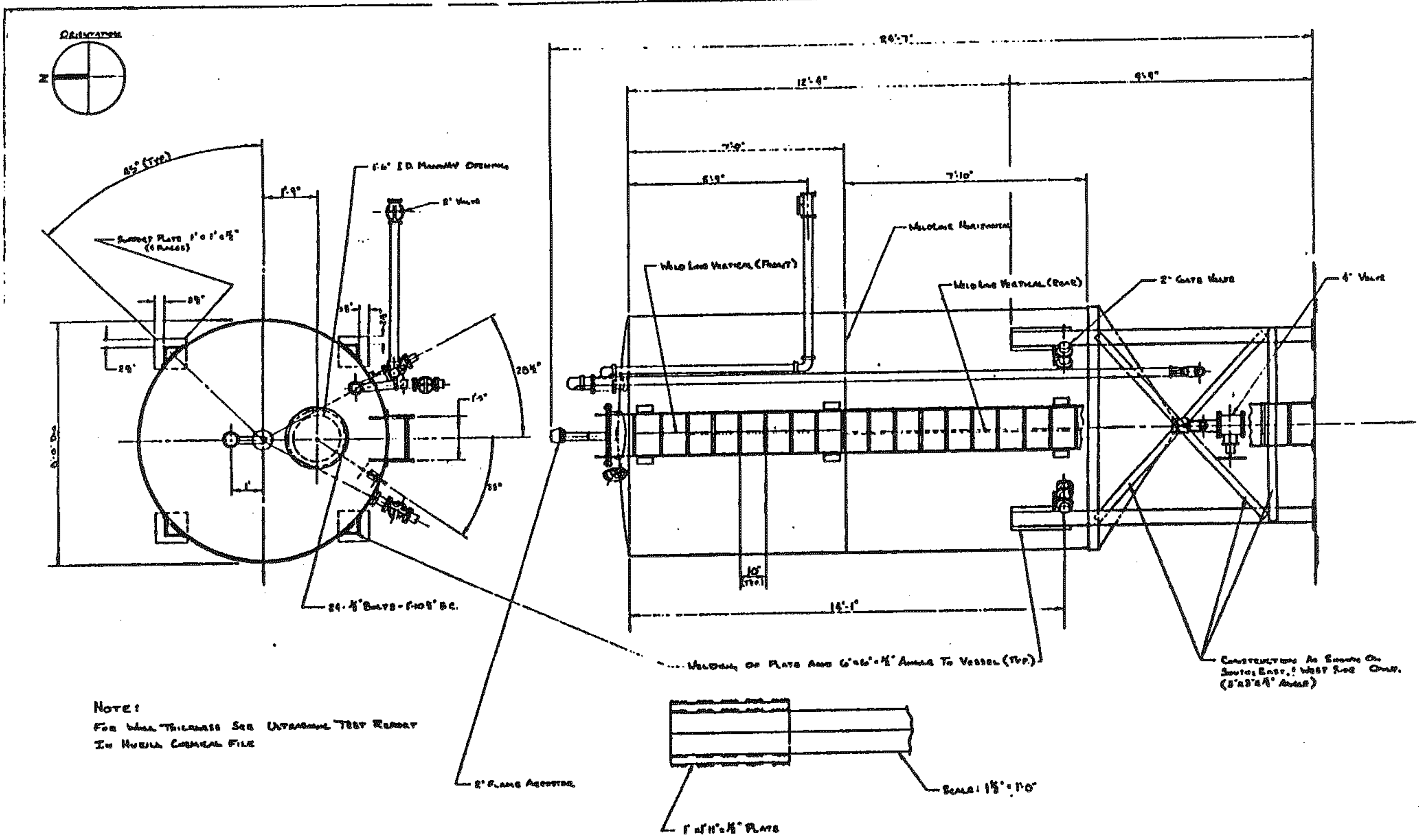
PLOT0011.DWG Rev. 1/3/92



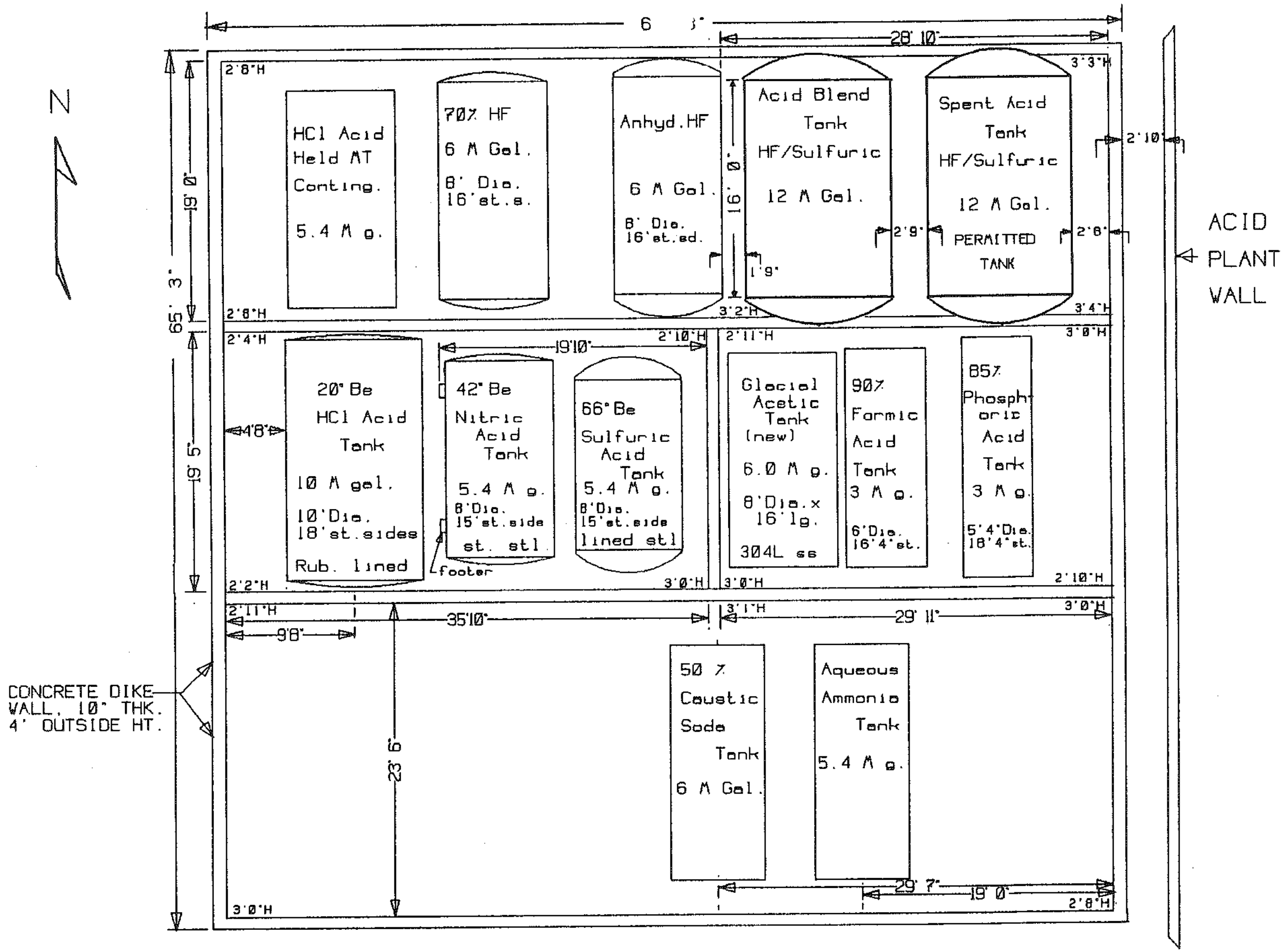
1/16" SCALE
TANK CAPACITY 16,093. GAL'S.
LADDER W/CAGE
4"-150# FLG.
6"-150# FLG.
20" M/W - KNAPP
HVY. EXP. METAL PLATFORM
1-4"-2-2"-150# FLG
4"-150# FLG.
5'6"
3 LIFTING LUGS @ 120°
120°
45°
12"
2"
12
2"-150# R.F. S.O. FLG.
4" VENT (FORGED FITTING)
LADDER CAGE EXTENDS 42" ABOVE PLATFORM
HAND RAIL AROUND PLATFORM ONLY
42"
8"
6"
4"-150# S.O. FLG.
TOP CONE 7GA.
90"
10'6" DIA.
SHELL, CONE & SUMP 1/4" PL.
23'1"
2"-150# S.O. FLG.
90"
31'8"
REINFORCING PL'S. 5/16" x 10" x 7'3" LG.
7'1"
7'3"
LADDER CAGE STARTS 8' ABOVE GROUND
6"
45°
6"-150# R.F. S.O. FLG
LEGS-6" H-BEAM @ 20# x 15' LG.
8"
7'11"
8'
REMOVABLE COVER 1/2" PL
24"
FLG. 5/16" PL
BASE PL 1" x 12" x 12"
BOTTOMS (SLUDGE) TANK
RAD TANK & WELDING CO., INC.
HUBBARD, OHIO 44425
12-14-78
V-117



Plan Sheet 14



Plan Sheet 15

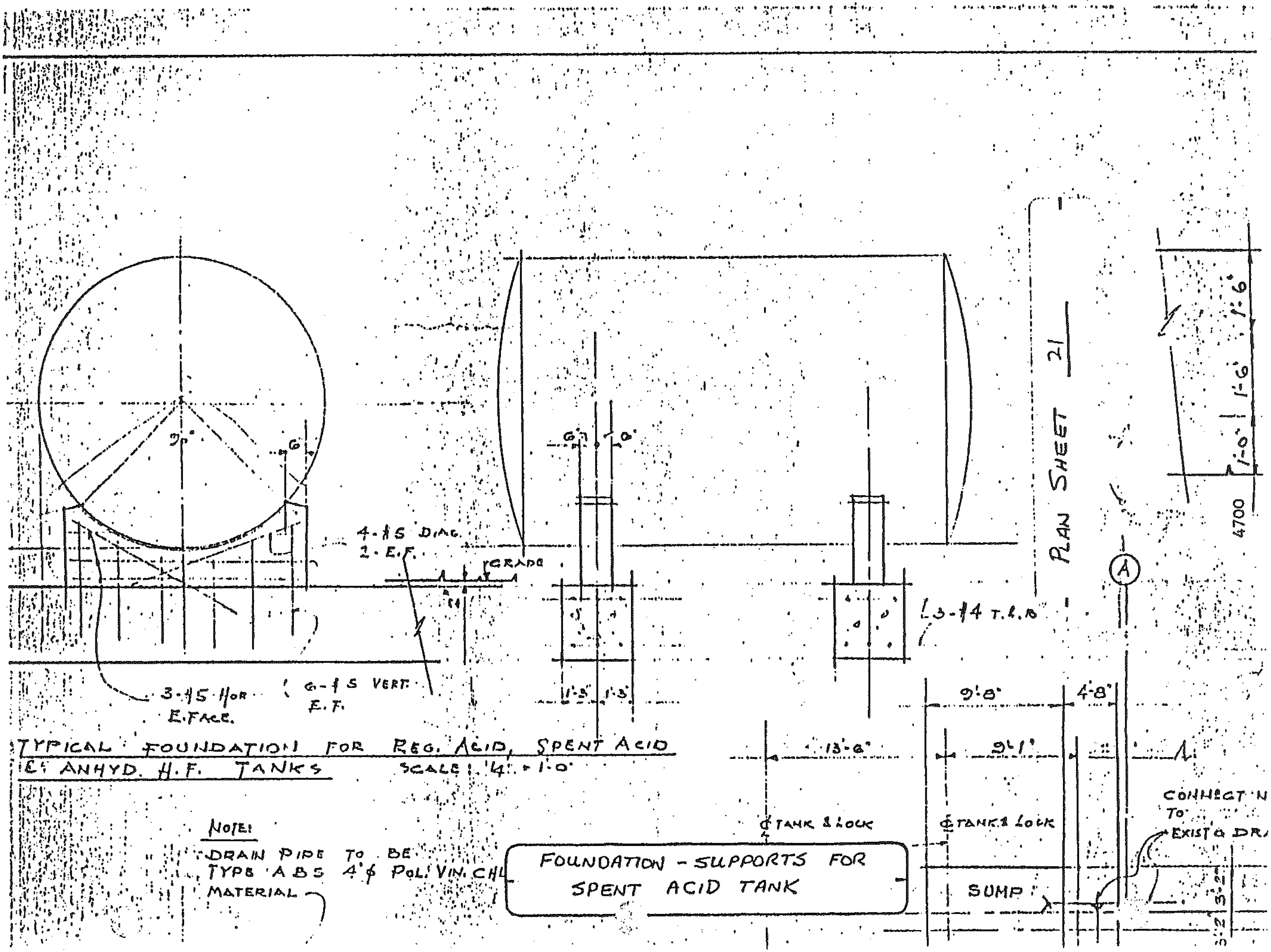


ACID PLANT TANK FARM

PLAN SHEET 20

HUKILL CHEMICAL CORPORATION

\ACIDPLT\ACID.GCD Rev. 4/4/95


4-#5 DIAG.
1- E.F.
GRADE
3-#5 Hor
E.FACE.
6-#5 VERT.
E.F.
1'-3"
1'-3"
L3-#4 T.L.B.
PLAN SHEET 21
A
4700
1'-0"
1'-6"
1'-6"
9'-8"
4'-8"
9'-1"
13'-6"
℄ TANK & LOCK
℄ TANK & LOCK
CONNECT'N TO EXIST'G DR.
SUMP
TYPICAL FOUNDATION FOR REG. ACID, SPENT ACID & ANHYD. H.F. TANKS
SCALE 1/4" = 1'-0"
NOTE:
DRAIN PIPE TO BE TYPE ABS 4"φ POL. VIN. CHL. MATERIAL
FOUNDATION - SUPPORTS FOR SPENT ACID TANK

Attachment B

Structural Assessment of a Hazardous Waste Storage Tank
for Hukill Chemical Company

References

[A] thru [F] Sketches of Tanks Elevations by Exhibit Groups

[1] Index of Tank Drawings and Sketches

[1.1] thru [1.12] Drawings and Sketches of Individual Tanks

[2.1] Chemical Engineers Handbook, Perry & Chilton, Page 6-96, Table 6-57

[2.2] Chemical Engineers Handbook, Perry & Chilton, Page 6-97, Table 6-59

[3.1] thru [3.15] Professional Service Industries Inc., Tank Wall Thickness Measurements Report No. 138-48041-001, Dated June 1994 and No. 138-48041-004, Dated Sept. 22, 1995

[4] The Engineers Manual, Hudson, page 18, Equation 53

[5] The Engineers Manual, Hudson, page 16, Equation 45

[6] The Engineers Manual, Hudson, page 13, Equation 33

[7] The Engineers Manual, Hudson, page 18, Equation 54

[8.1] Manual of Steel Construction, 9th Edition, AISC, page 1-111

[8.2] Ryerson Stock List Catalogue, page 217

[9] Manual of Steel Construction, AISC, 9th Edition, page 4-5, Table 1-D

[10] Sketch of Rivet Patterns Tanks V-114 thru V-614

[11] Structural Engineering Handbook, Gaylord & Gaylord, Chapter 23

[12] Manual of Steel Construction, AISC, 9th Edition, page 5-33, Paragraph B.2

[13] Manual of Steel Construction, AISC, 9th Edition, page 5-75, Eq. J3-6

Structural Assessment of a Hazardous Waste Storage Tank for Hukill Chemical Company

References

[14] Index of Dike Wall Drawings & Sketches

[14.1] thru [14.3] Drawings and Sketches of Individual Dike Walls

[15] Reinforced Concrete Design Handbook, ACI Publication SP-3, page 85, Table 3b

[16] Reinforced Concrete Design Handbook, ACI Publication SP-3, page 81, Table 1

[17] Manual of Steel Construction, 9th Edition, AISC, pages as noted.

[18] Equations for Retaining Wall Design

[19] Pressure Vessel Handbook, 3rd Edition, Eugene F. Megyesy, pages as noted

[20a] [20b] Extrapolation of Values, Pressure Vessel Handbook, 3rd Edition, Eugene F. Megyesy, page 76

[21] Report of Soils Investigation by EDP/Triggs Consultants, Inc., dated July 7, 1988

[22] Chemical Engineers Handbook, Fifth Edition, pages as noted.

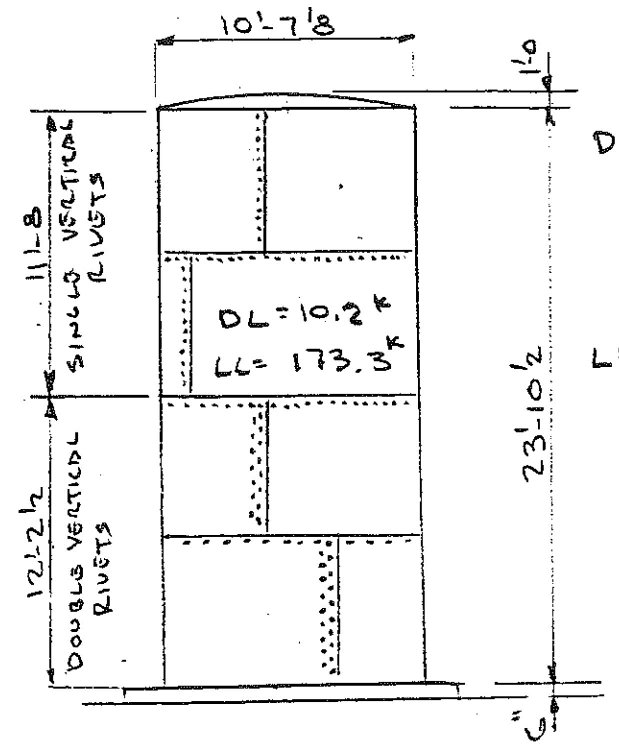
[23] Formulas for Stress and Strain, Fifth Edition, Roark and Young, pages as noted.

Structural Assessment of a Hazardous Waste Storage Tank
for Hukill Chemical Company

7 Tank Dike System - Tanks V-114 thru V-614;
V-120; V-4000C; V-1500C

Exhibit D-2

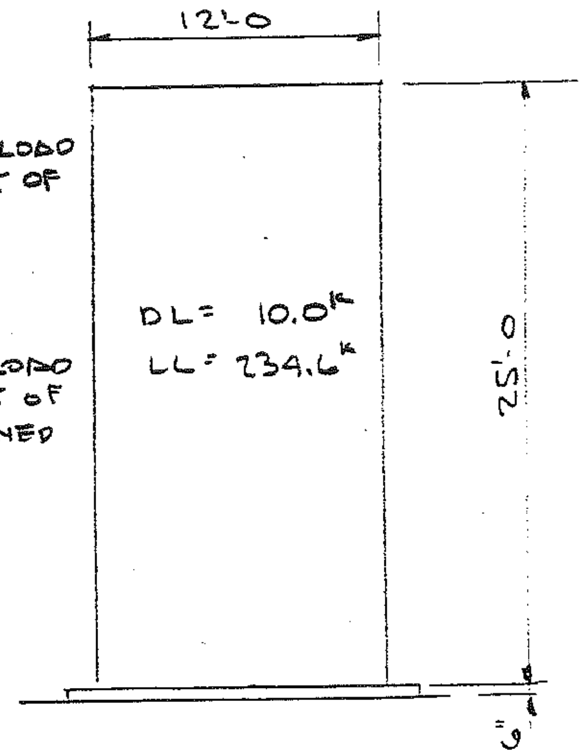
TANKS V-114 THRU V-614



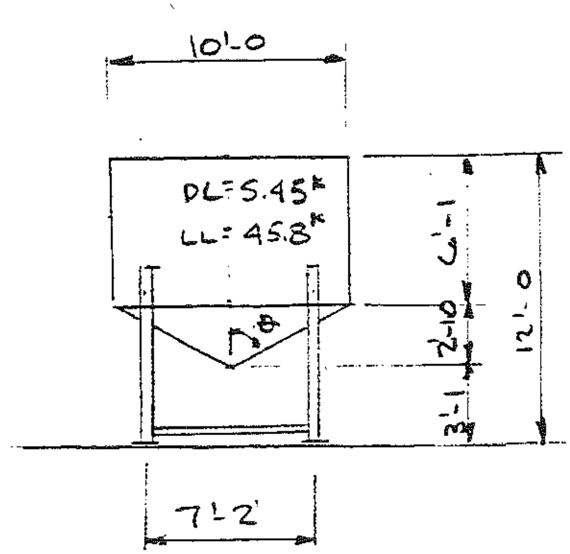
DL = DEAD LOAD WEIGHT OF TANK

LL = LIVE LOAD WEIGHT OF CONTAINED LIQUID

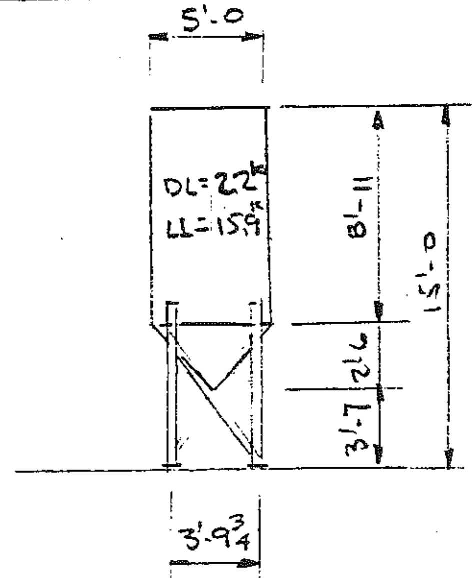
TANK V-120 SS



TANK V-4000 C



TANK V-1500 C



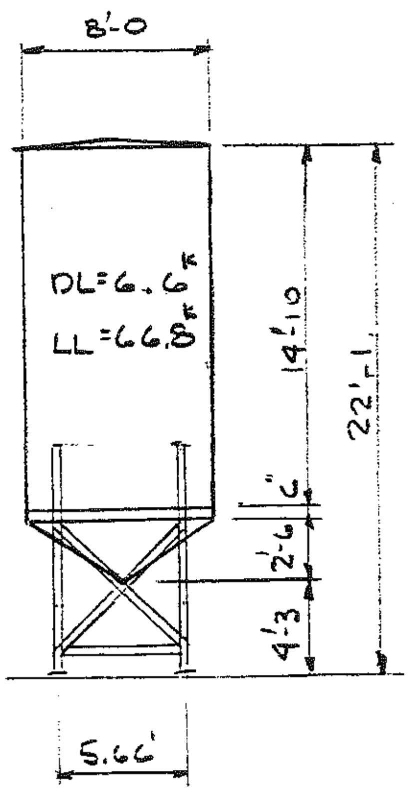
[A]

Structural Assessment of a Hazardous Waste Storage Tank
for Hukill Chemical Company

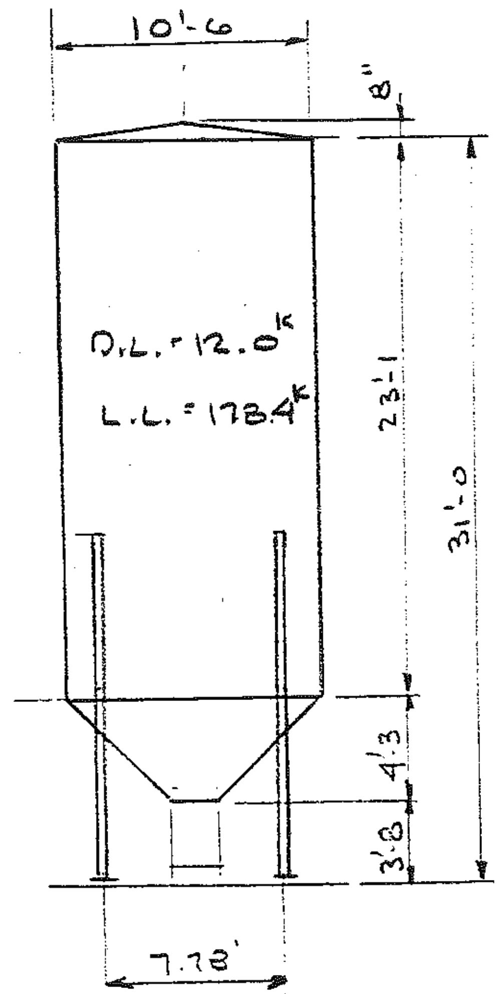
BTMS/Feed Tanks
Tanks East 6/M; West 6/M; V-117

Exhibit D-10

TANKS: EAST / 6M
WEST / 6M



TANK BTMS V-117



D.L. = DEAD LOAD
WEIGHT OF TANK

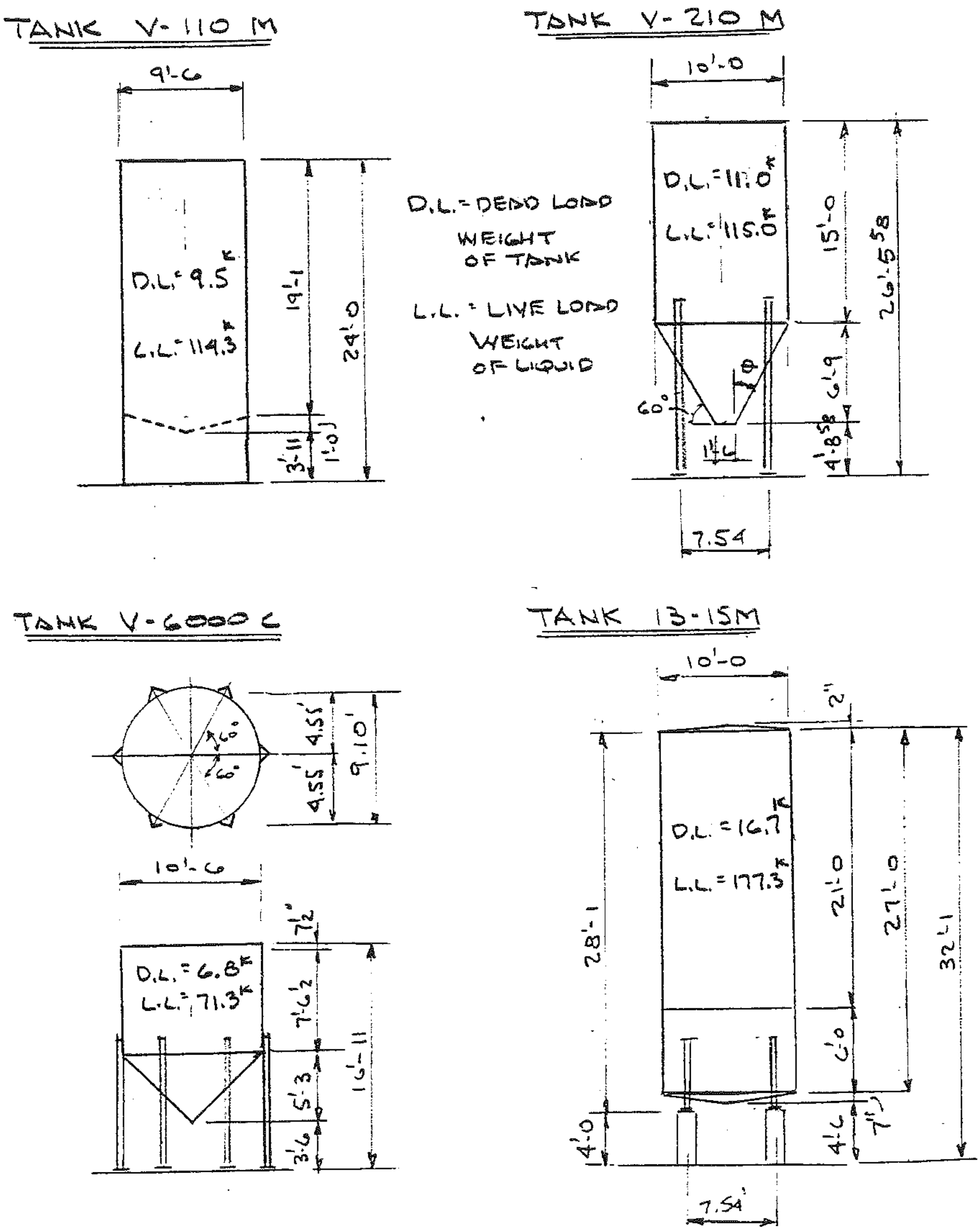
L.L. = LIVE LOAD
WEIGHT OF CONTAINED LIQUID

[B]

Structural Assessment of a Hazardous Waste Storage Tank
for Hukill Chemical Company

F-1 Fuels Dike
Tanks V-110; V-210; V-6000; 13-15M

Exhibit D-6



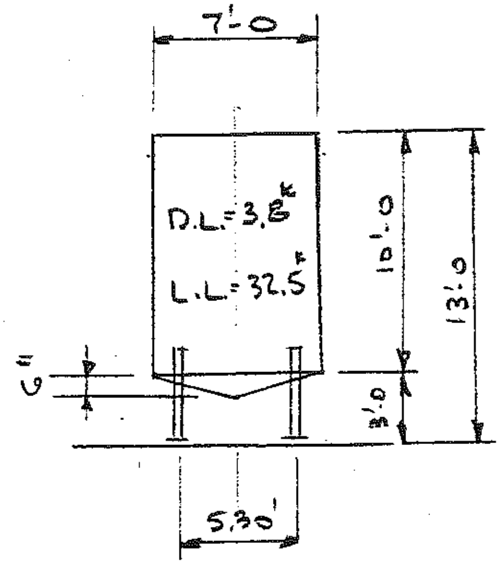
[C]

Structural Assessment of a Hazardous Waste Storage Tank
for Hukill Chemical Company

4 X 3M Feed Tanks
Tanks 8-3-F thru 11-3-F

Exhibit D-7

TANKS 8-3-F, 9-3-F, 10-3-F & 11-3-F



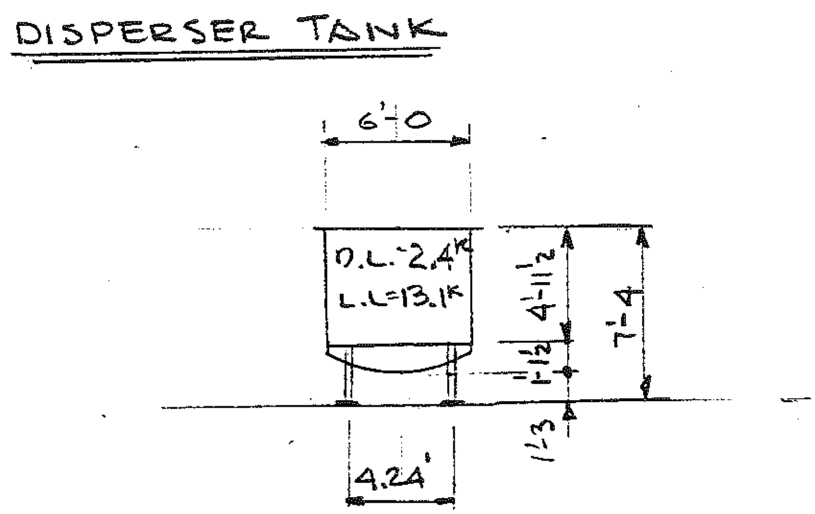
D.L. = DEAD LOAD
WEIGHT OF TANK

L.L. = LIVE LOAD
WEIGHT OF LIQUID

Structural Assessment of a Hazardous Waste Storage Tank
for Hukill Chemical Company

Disperser Tank

Exhibit D-8



D.L. = DEAD LOAD
WEIGHT OF TANK

L.L. = LIVE LOAD
WEIGHT OF LIQUID

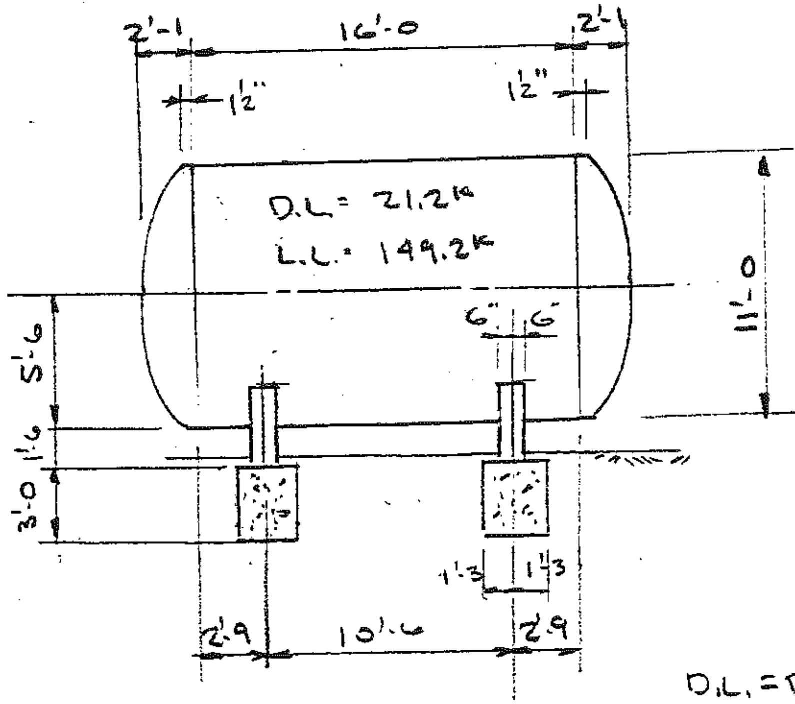
[E]

Structural Assessment of a Hazardous Waste Storage Tank
for Hukill Chemical Company

Spent Acid Tank

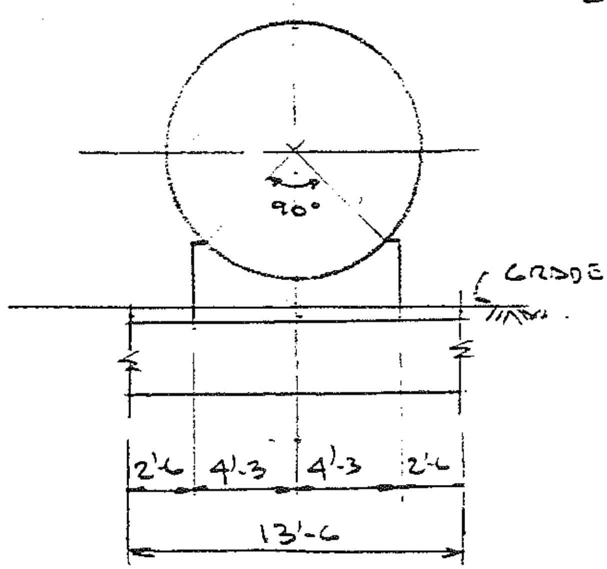
Exhibit D-9

SPENT ACID TANK



D.L.=DEAD LOAD
WEIGHT OF TANK

L.L.= LIVE LOAD
WEIGHT OF LIQUID

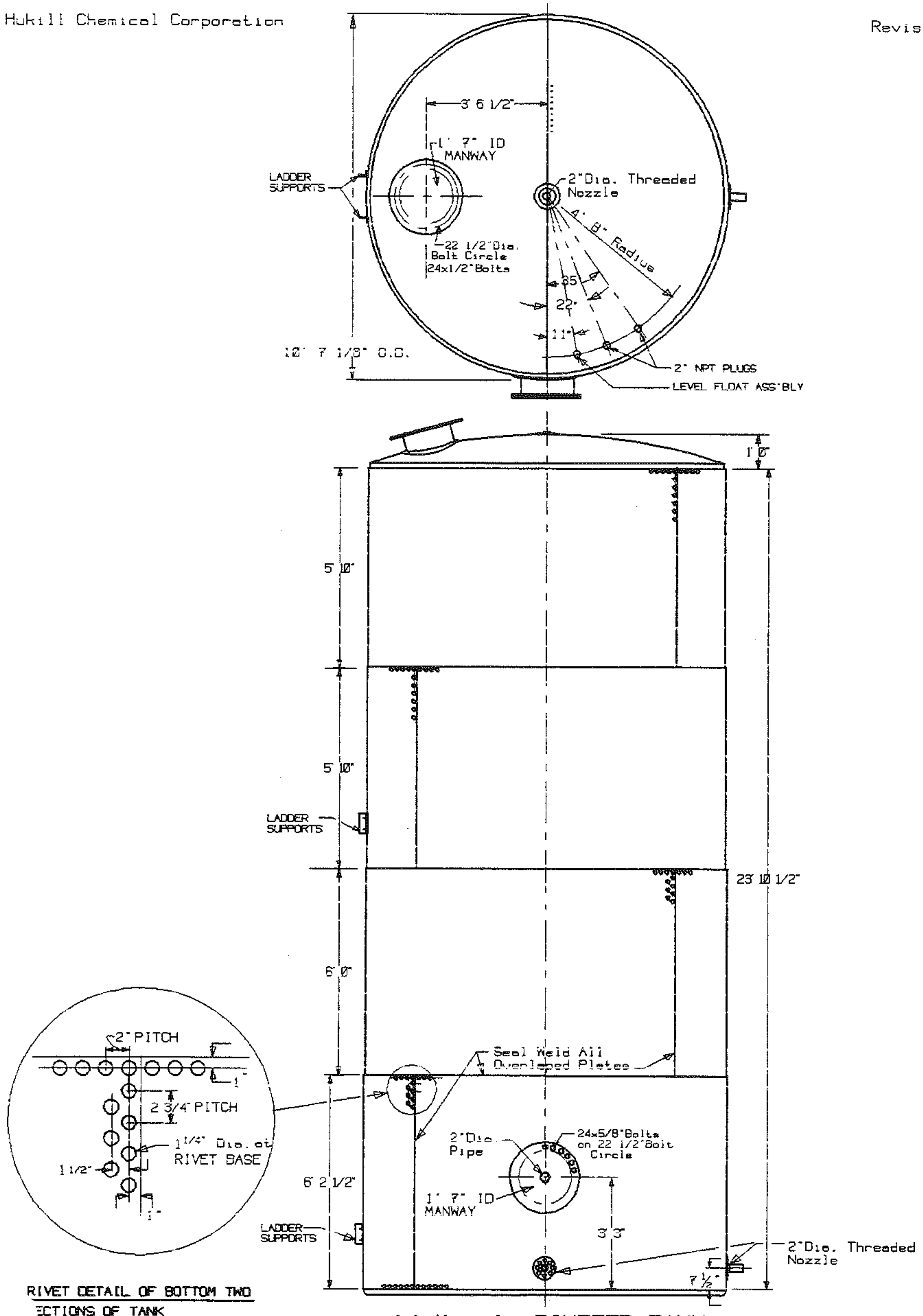


[F]

Structural Assessment of a Hazardous Waste Storage Tank for Hukill Chemical Company

Index of Tank Drawings and Sketches

Dike I.D.	Exhibit	Tank Elevation Sketch Sheet	Tanks	Ref.	Drawing Description
7 Tank Dike	D-2	[A]	V-114 thru V-614	[1.1]	H.C.C. Sketch
			V-120-SS	[1.2]	H.C.C. Reduced Drawing
			V-4000C	[1.3]	H.C.C. Sketch
			V-1500C	[1.3]	H.C.C. Sketch
BTMS/Feed	D-10	[B]	East/6M	[1.4a]	H.C.C. Reduced Drawing Plan Sheet 14
			West/6M	[1.4b]	H.C.C. Reduced Drawing Plan Sheet 15
			V-117	[1.5]	R.A.D. Tank & Welding Co. Inc. Reduced Sketch Plan Sheet 13
F-1 Fuels Dike	D-6	[C]	V-110	[1.6]	H.C.C. Sketch
			V-120	[1.7]	H.C.C. Reduced Drawing
			V-6000C	[1.8]	H.C.C. Sketch
			13-15M	[1.9a]	Hamilton Tank Reduced Drawing
				[1.9b]	H.C.C. Sketch
4X3M Feed Tanks	D-7	[D]	8-3-F thru 11-3-F	[1.10a]	Hamilton Tank Reduced Drawing
				[1.10b]	Enlarged Elevation
Disperser Tank	D-8	[E]	Dispr. Tanl	[1.11]	H.C.C. Sketch
Spent Acid Tank	D-9	[F]	Spent Acid	[1.12a]	12,000 Gal. Horizontal Vessel Drawing Part B, Book 2, Plan Sheet 19
				[1.12b]	Partial Drawing Foundation & Supports Plan Sheet 21



14 M gal. RIVETED TANK

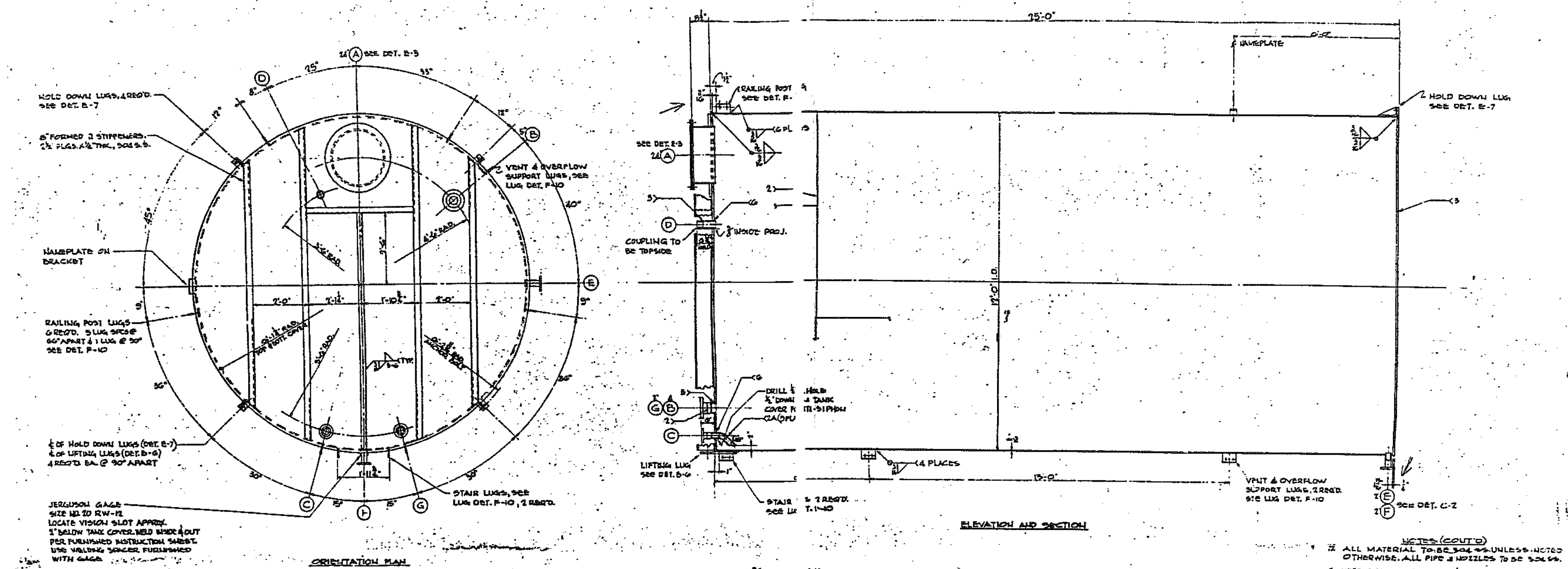
(Constructed of 3/8" C.S. Plate with 3/4" Rivets)

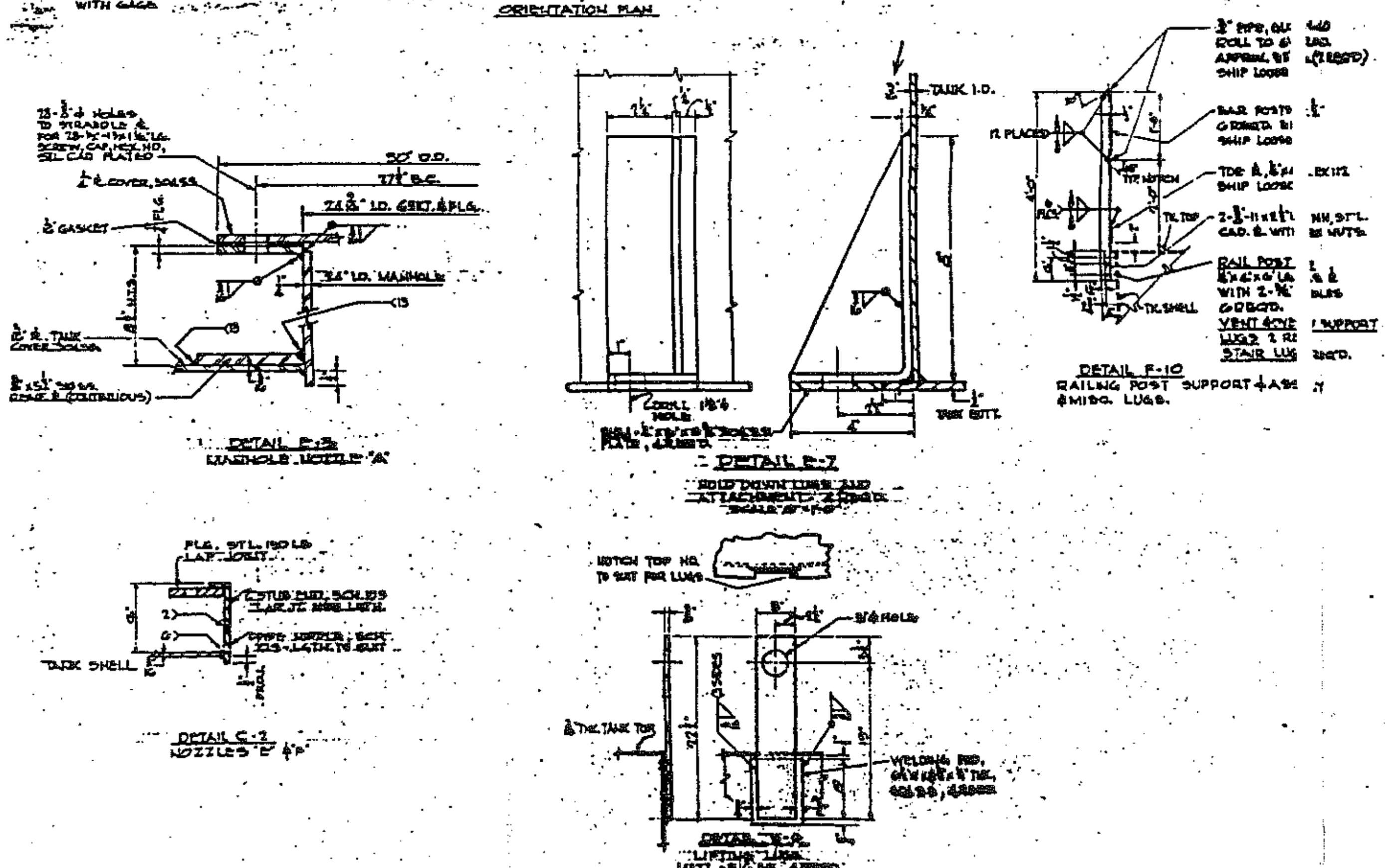
HUKILL CHEMICAL CORPORATION

\PARTB-10\14MTKS.GCD Rev. 3/11/96

Scale: 1/4" = 1'

E143XX-620-002





NOTES (CONT'D)

7. ALL MATERIAL TO BE 304 SS UNLESS NOTED OTHERWISE. ALL PIPE & NOZZLES TO BE 304 SS.
8. WIRE BRUSH ALL WELDS & CLEANSE INTERIOR
9. PROVIDE PLUGS OR COVERS ON ALL OPENINGS AFTER CLEANING.
10. ALL GASKETS TO BE 1/8" THK. ASBESTOS, GARLOCK 900 OR EQUAL
11. RAILING TO BE SHOP FAB. & FIELD INSTALLED AFTER TANK ERECTION. RAILING FINISH TO BE KOPPERS BITUMASTIC BLACK.
12. WHEN LIFTING TANK USE SPREADER BARS
13. WHEN TANK IS HORIZONTAL SUPPORT CYLINDRICAL SHELL IN CRADLE FOR FULL LENGTH OF SHELL.
14. STRAIGHT SIDE SHELL = 70.5 GAL/IN.
= 846 GAL/FT.

NOZZLE SCHEDULE

NOZ.	SIZE	SERVICE	DESCRIPTION
A	24"	MANHOLE	SEE DET. E-3
B	4"	VENT AND OVERFLOW	STUB END SCH. 5S MSS, 304L SS & 304L SS PIPE SCH 5S/W 150# L.J. FLG. ST'L.
C	2"	FILL	STUB END SCH 10S MSS, 304L SS & 304L SS PIPE SCH 10S/W 150# L.J. FLG. ST'L.
D	2½"	HIGH LEVEL	COUPLING, 150# SCR. 316 SS & 3" SCH. 40 PIPE 304SS
E	2"	LEVEL INDICATOR	SEE DET. C-2
F	2"	DRAW-OFF	SEE DET. C-2
G	2"	SPARE	STUB END SCH 10S MSS 304L SS & 304L SS PIPE SCH 10S/W 150# L.J. FLG. ST'L.

UNFIRED PRESSURE VESSEL SPECIFICATIONS

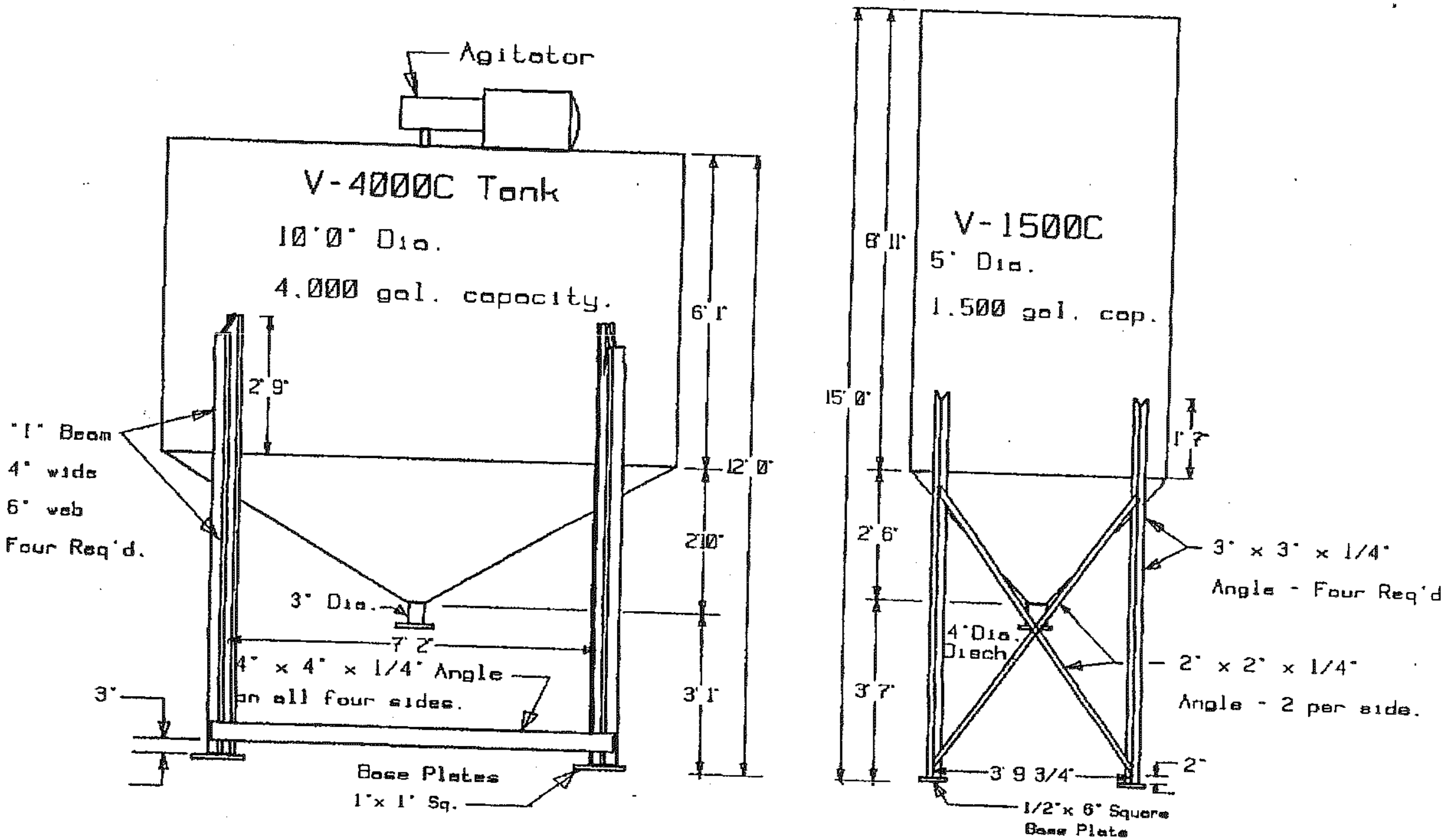
VESSEL NO. C-554 INSURED FM
FABRICATED TO 19 68 A.S.M.E. CODE UNFIRED VESSELS
INSP. BY O INT'L 2 YR.
WGT. EMPTY 10,600 LBS. FULL 241,400 LBS.
CAP. STR. SIDE GALS. 21,150

Hukill Chemical
V-120
Rec'd 7/24/89

D

21,000 GAL STORAGE TANK
ITEM 7110 AMMONIUM HYPO 304 SS
SOUTH OF BLDG 143

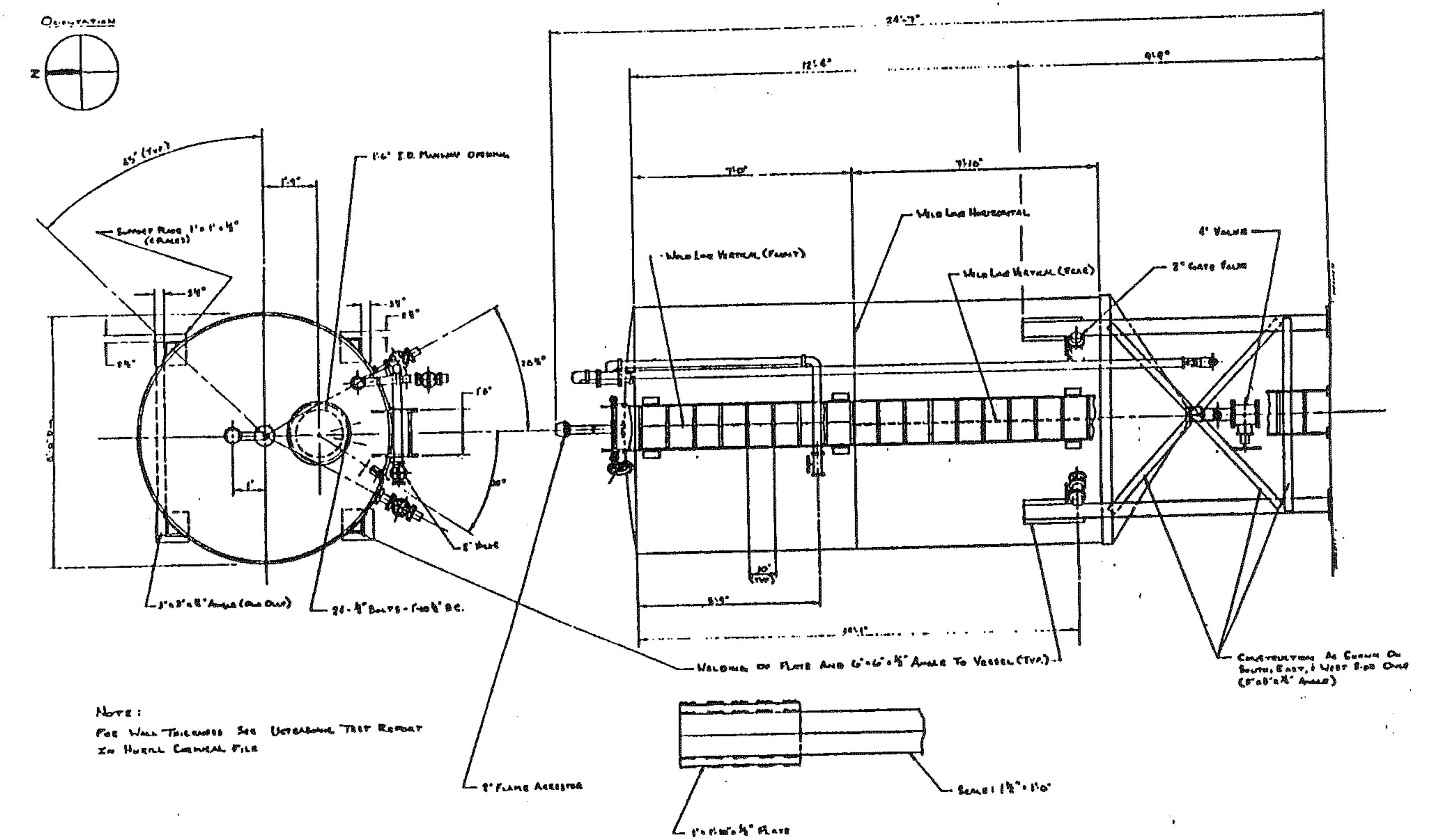
BLDG. NO. 143
LOCATION KFW
DRAWN OLSHESKI DATE 6-71
DESIGN SUPERVISOR D. TRIPP
E143XX-620-002



Hukill Chemical Corporation

\PARTB-10\90DAT<S.GCD Rev. 9/5/95

Scale: 1" = 3'

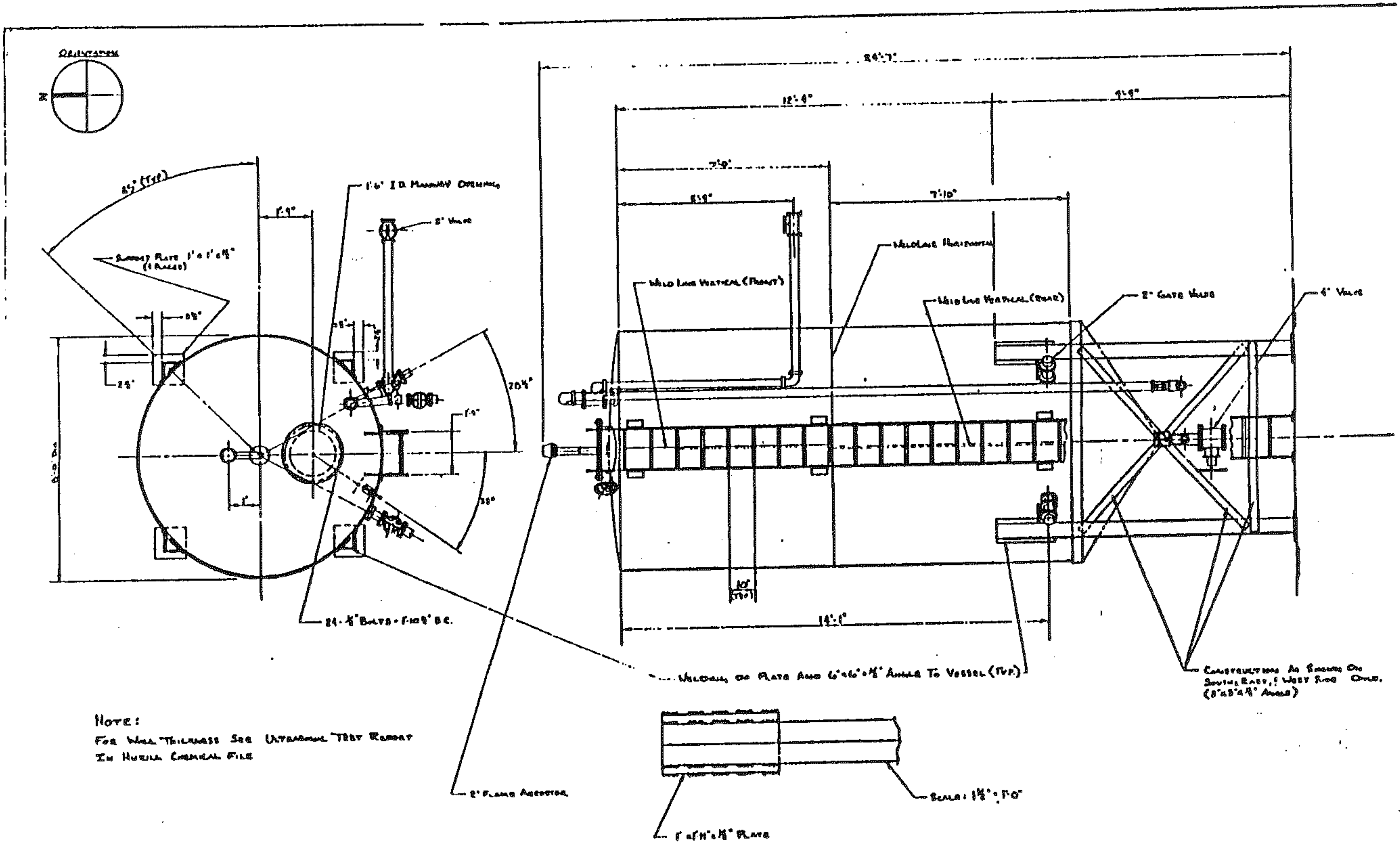


Note:
For Wall Thickness See Ultrasonic Test Report
In Hukill Chemical File

Plan Sheet 14

Hukill Chemical Corp		
Feb. 9, 1981	6000 East Field	

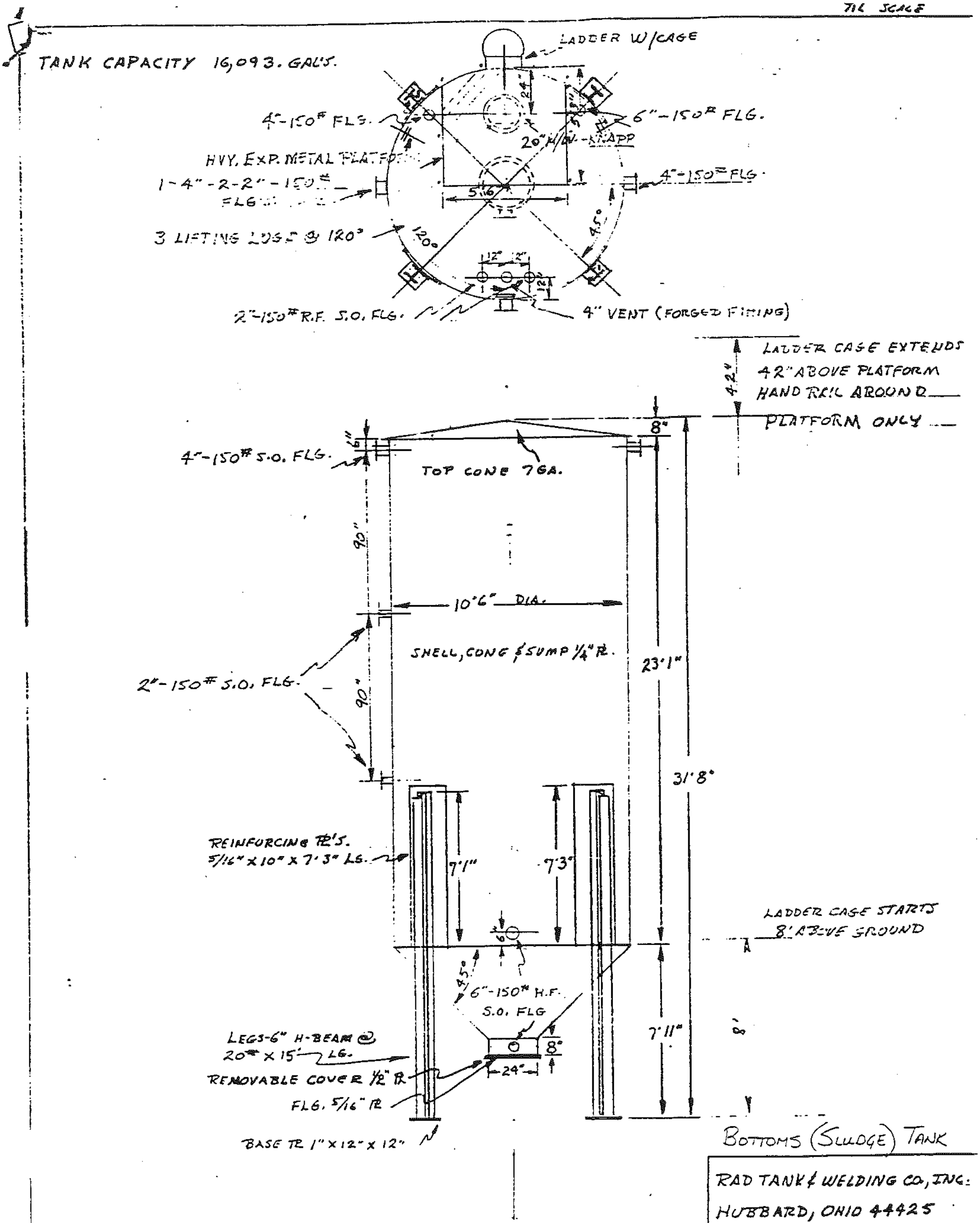
1.4a



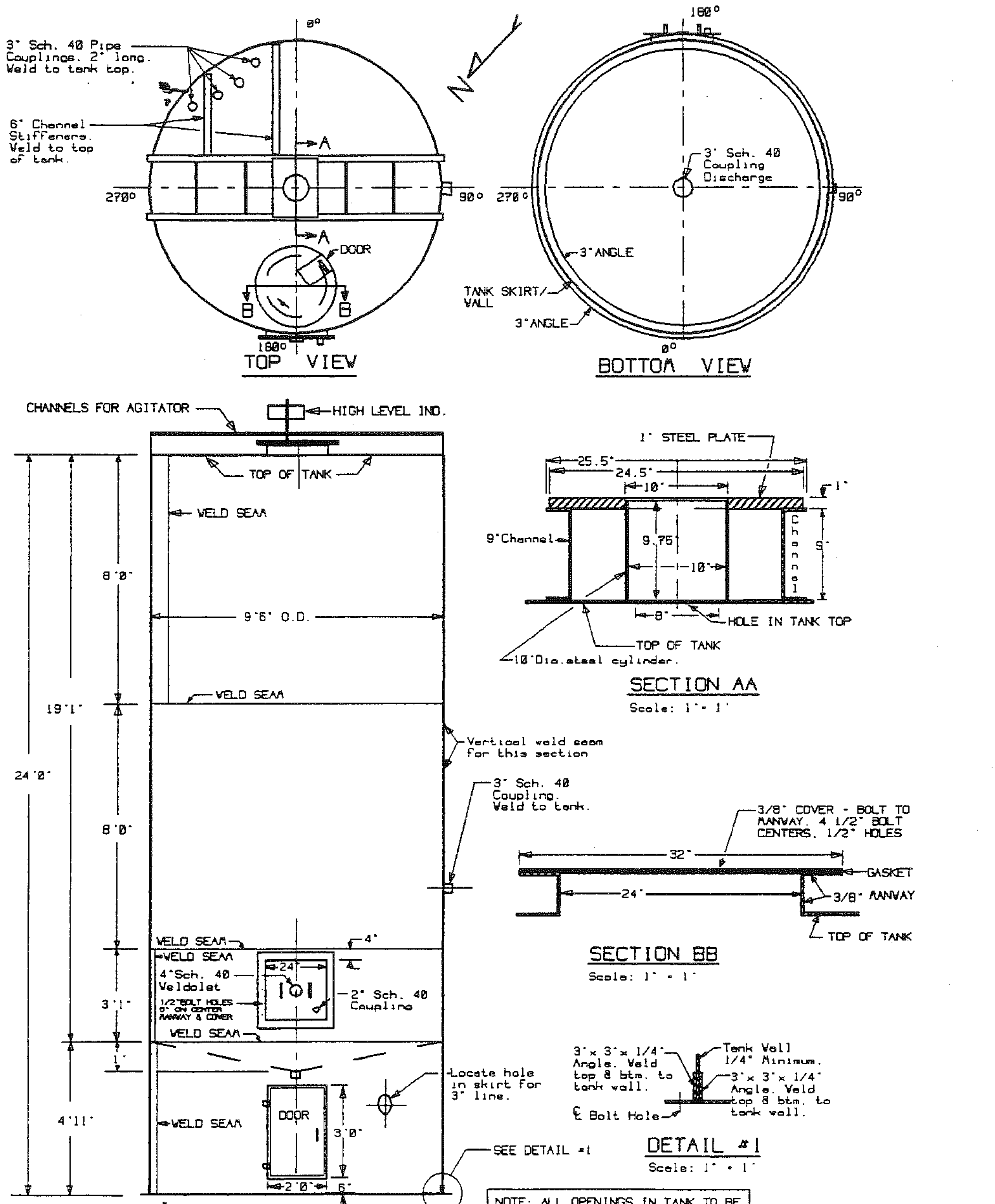
Note:
For Wall Thickness See Ultrasonic Test Report
In Hukill Chemical File

Plan Sheet 15

Hukill Chemical Corp	
6000 West Feed	



7/L SCALE
TANK CAPACITY 16,093. GAL'S.
LADDER W/CAGE
4"-150# FLG.
6"-150# FLG.
20" M/W - KNAPP
HVY. EXP. METAL PLATFORM
1-4"-2-2"-150# FLG.
4"-150# FLG.
5'6"
24"
45°
3 LIFTING LUGS @ 120°
120°
12"
12"
2"-150# R.F. S.O. FLG.
4" VENT (FORGED FITTING)
LADDER CAGE EXTENDS 42" ABOVE PLATFORM HAND RAIL AROUND PLATFORM ONLY
42"
8"
4"-150# S.O. FLG.
6"
TOP CONE 7GA.
90"
10'6" DIA.
SHELL, CONE & SUMP 1/4" PL.
23'1"
2"-150# S.O. FLG.
90"
31'8"
REINFORCING PL'S. 5/16" x 10" x 7'3" LG.
7'1"
7'3"
LADDER CAGE STARTS 8' ABOVE GROUND
6"
45°
6"-150# H.F. S.O. FLG
7'11"
8'
LEGS-6" H-BEAM @ 20# x 15' LG.
8"
REMOVABLE COVER 1/2" PL
24"
FLG. 5/16" PL
BASE PL 1" x 12" x 12"
BOTTOMS (SLUDGE) TANK
RAD TANK & WELDING CO, INC.
HUBBARD, OHIO 44425
12-14-78 V-117



NOTE: ALL OPENINGS IN TANK TO BE VAPOR TIGHT. FOR USE WITH FLAMMABLE LIQUIDS.

V-110M STORAGE TANK

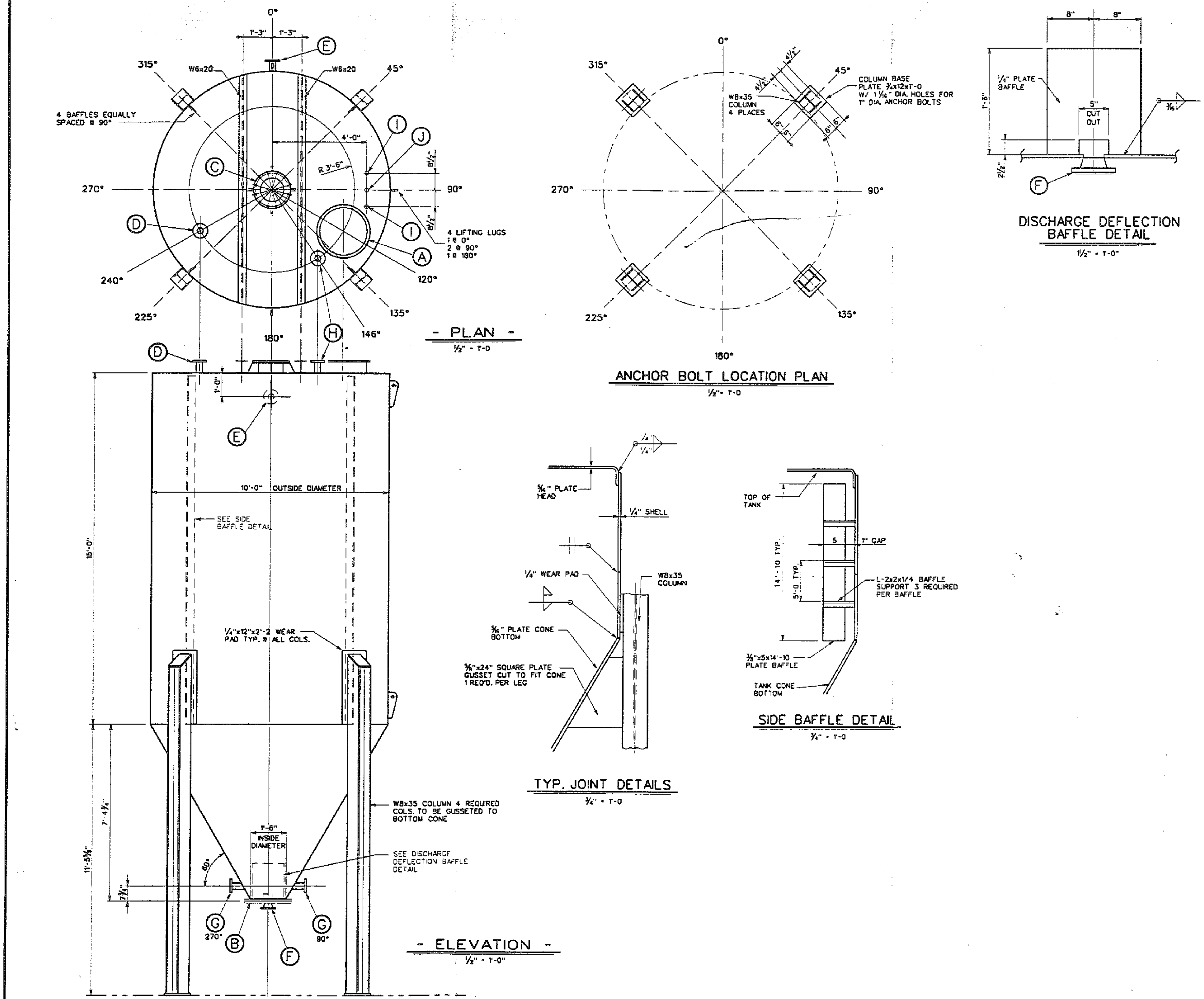
Construct tank walls, cone and top of 1/4 inch carbon steel. Must be min. of 1/4 inch for walls and cone

HUKILL CHEMICAL CORPORATION

\TANKS\V-110M.DWG Rev. 2/10/92

Scale: 1/4" = 1' (48)

1.6



Nozzle Schedule

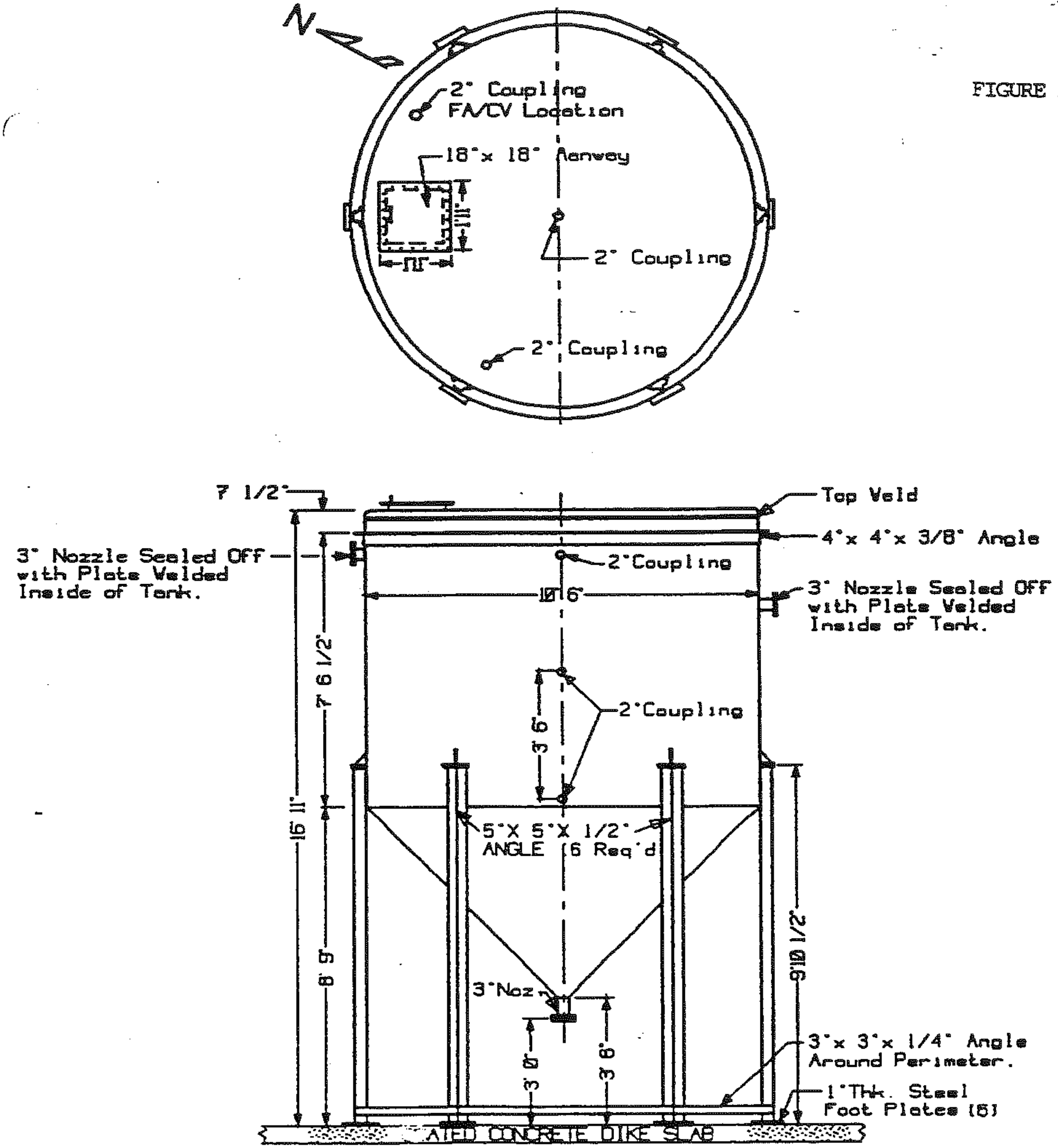
MARK	DESCRIPTION	QUAN	PROJ.	REMARKS
A	24" STD. PRESSED MANHOLE	1	6"	EXTENDED W/ LONG BOLTS
B	18" MANHOLE RING	1	--	W/ COVER
C	12" 150# SLIP ON FLANGE	1	6"	GUSSETED
D	3" 150# SLIP ON FLANGE	1	6"	VENT
E	3" 150# SLIP ON FLANGE	1	6"	OVERFLOW
F	3" 150# WELD NECK FLANGE	1	2 3/8"	IN MANHOLE COVER
G	3" 150# SLIP ON FLANGE	2	6"	
H	3" 150# SLIP ON FLANGE	1	6"	
I	1 1/4" 150# HALF COUPLING	2	--	LEVEL GUAGE
J	1 1/2" 150# HALF COUPLING	1	--	LEVEL GUAGE

Notes:

1. ALL MATERIAL TO H.R. CARBON STEEL
2. DESIGN AND OPERATING PRESSURE - ATMOSPHERIC.
3. ALL BOLT HOLES TO STRADDLE FITTING CENTERLINES.
4. ESTIMATED WEIGHT EMPTY = 12,438#
5. TANK TO BE BUILT & LABELED PER U.L. SPEC. #142.

HUKILL CHEMICAL CORP.	DRAWN T. MULKA DATE	TANK V210M
	CHECKED DATE	TANK AS BUILT DRAWING
HAW ASSOCIATES	SCALE NOTED	DRAWING NO. 1819-T1

FIGURE 2



V-6000C STORAGE TANK

(Tank No. 166)

NOTE: Tank sides and cone constructed of 1/4 inch carbon steel. Orig. built as an open top tank. Top welded on at a later date.

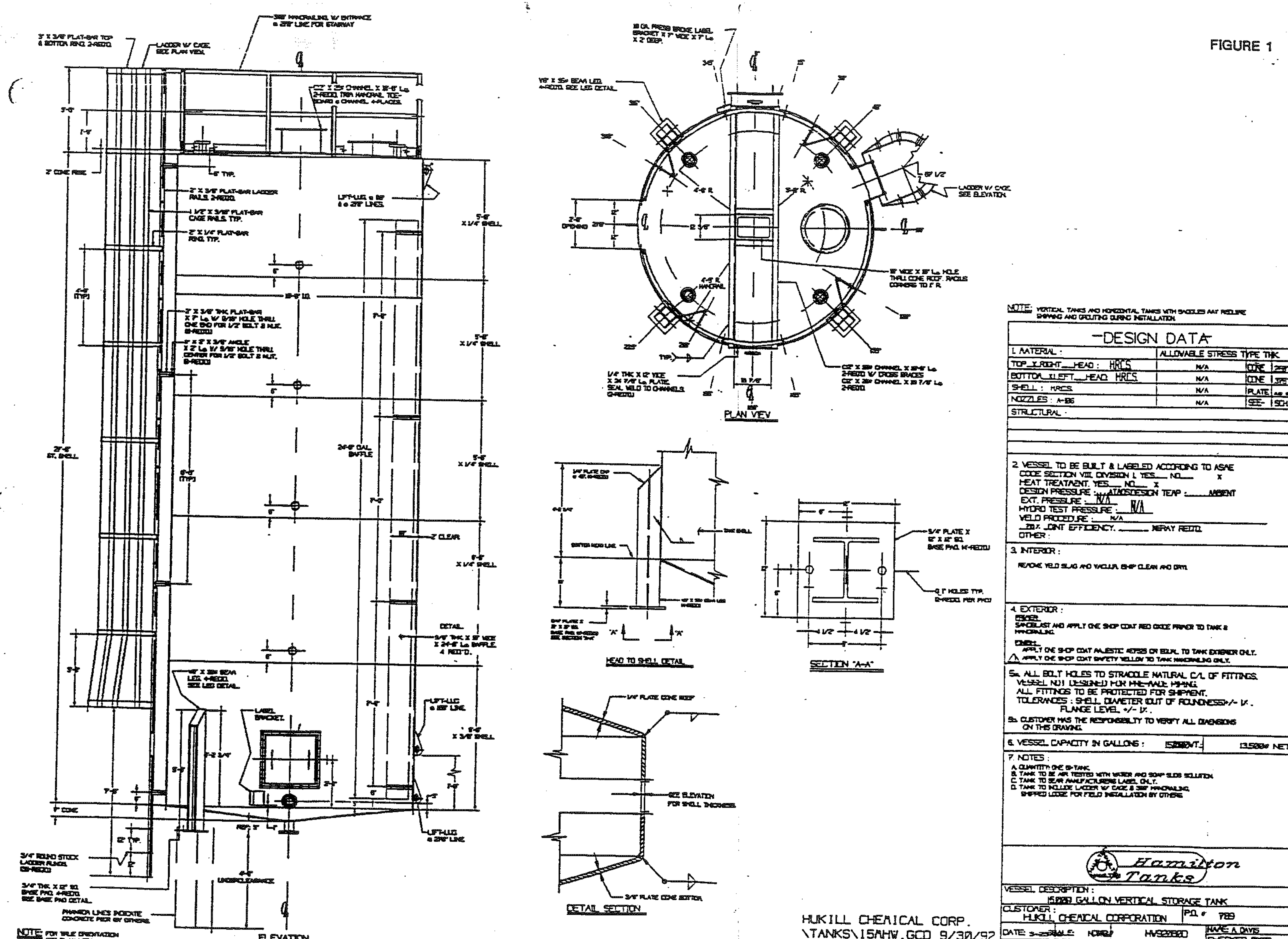
HUKILL CHEMICAL CORPORATION

\PARTB-5\V6000CTK.GCD Rev. 6/9/94

Scale: 1/4" = 1'

[1.8]

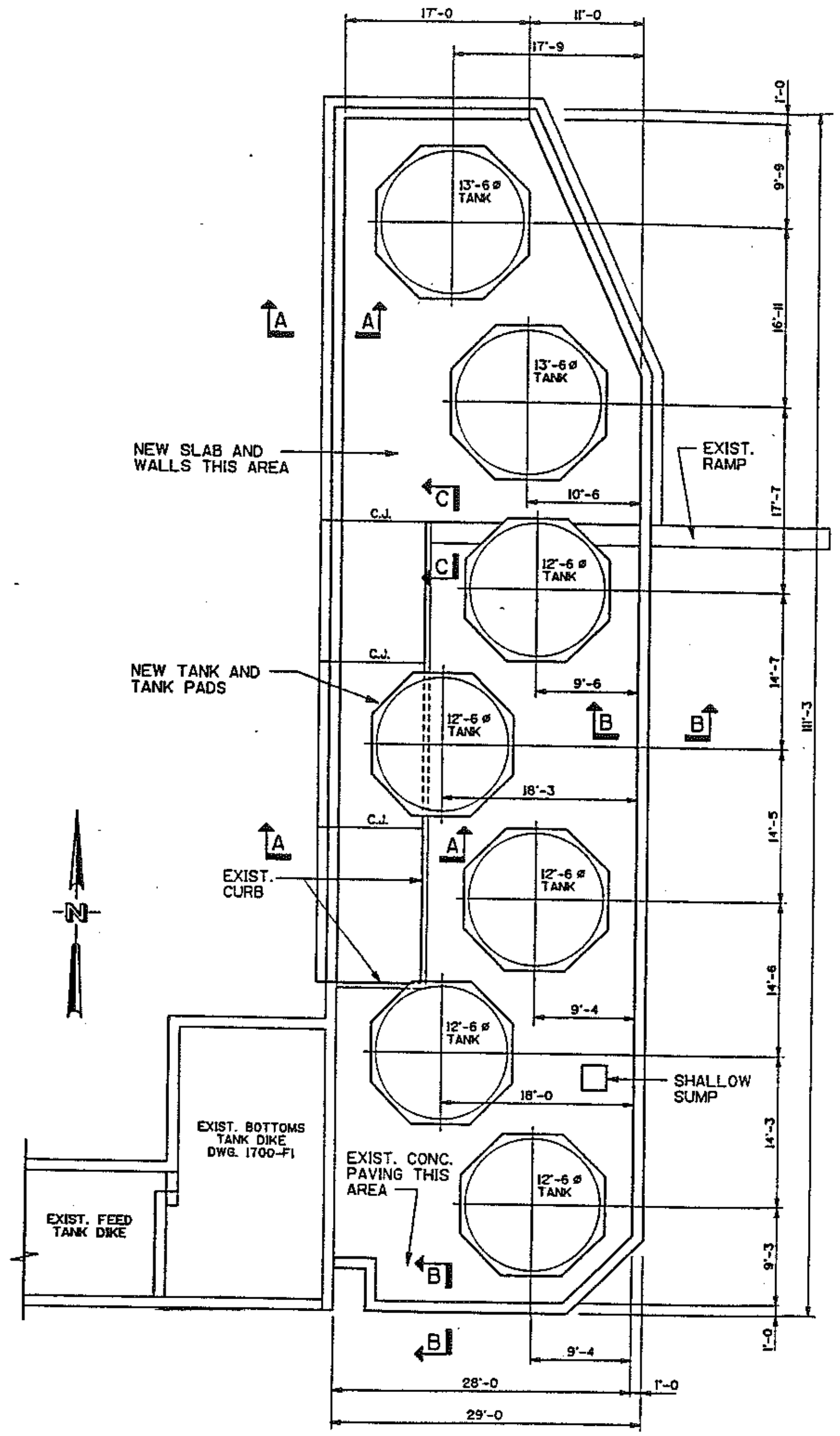
FIGURE 1



15,000 GAL. 90-DAY GENERATOR TANK

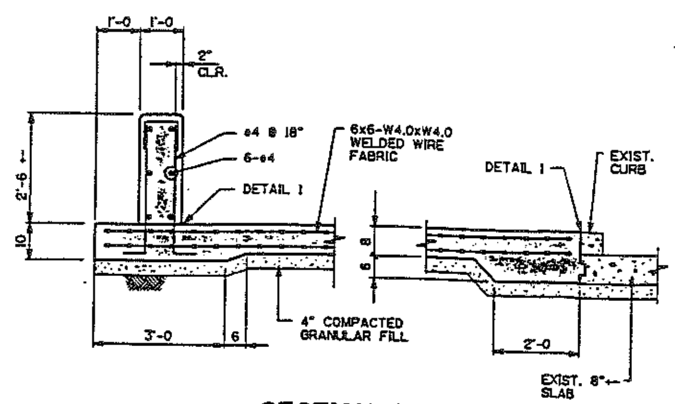
HUKILL TANK I.D. IS 13-15A

[1.9a]



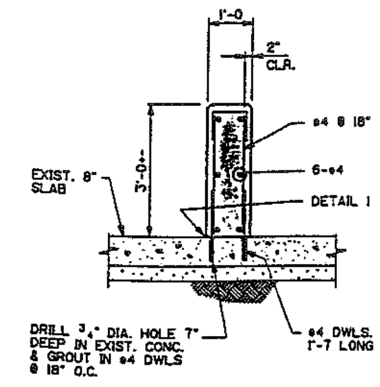
PLAN - EAST PAD AREA HAZARDOUS WASTE STORAGE TANK DIKE

SCALE: 1/8" = 1'-0"



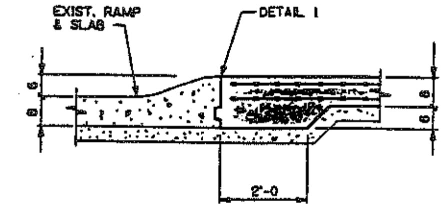
SECTION A-A

SCALE: 1/2" = 1'-0"



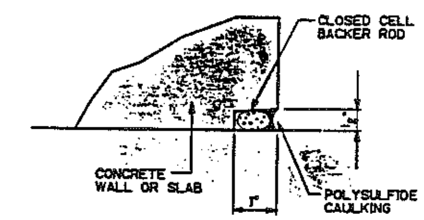
SECTION B-B

SCALE: 1/2" = 1'-0"



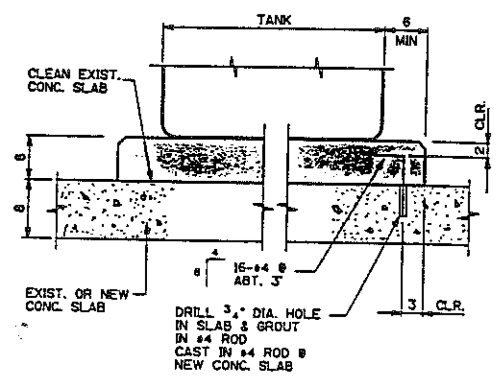
SECTION C-C

SCALE: 1/2" = 1'-0"



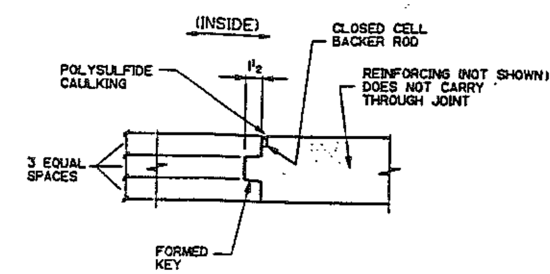
DETAIL 1

TYP. AT ALL JOINTS IN CONCRETE



TYP. TANK PAD DETAIL

SCALE: 1" = 1'-0"



TYP. CONTROL / CONSTRUCTION JOINT IN BASE SLAB & WALLS

Notes:

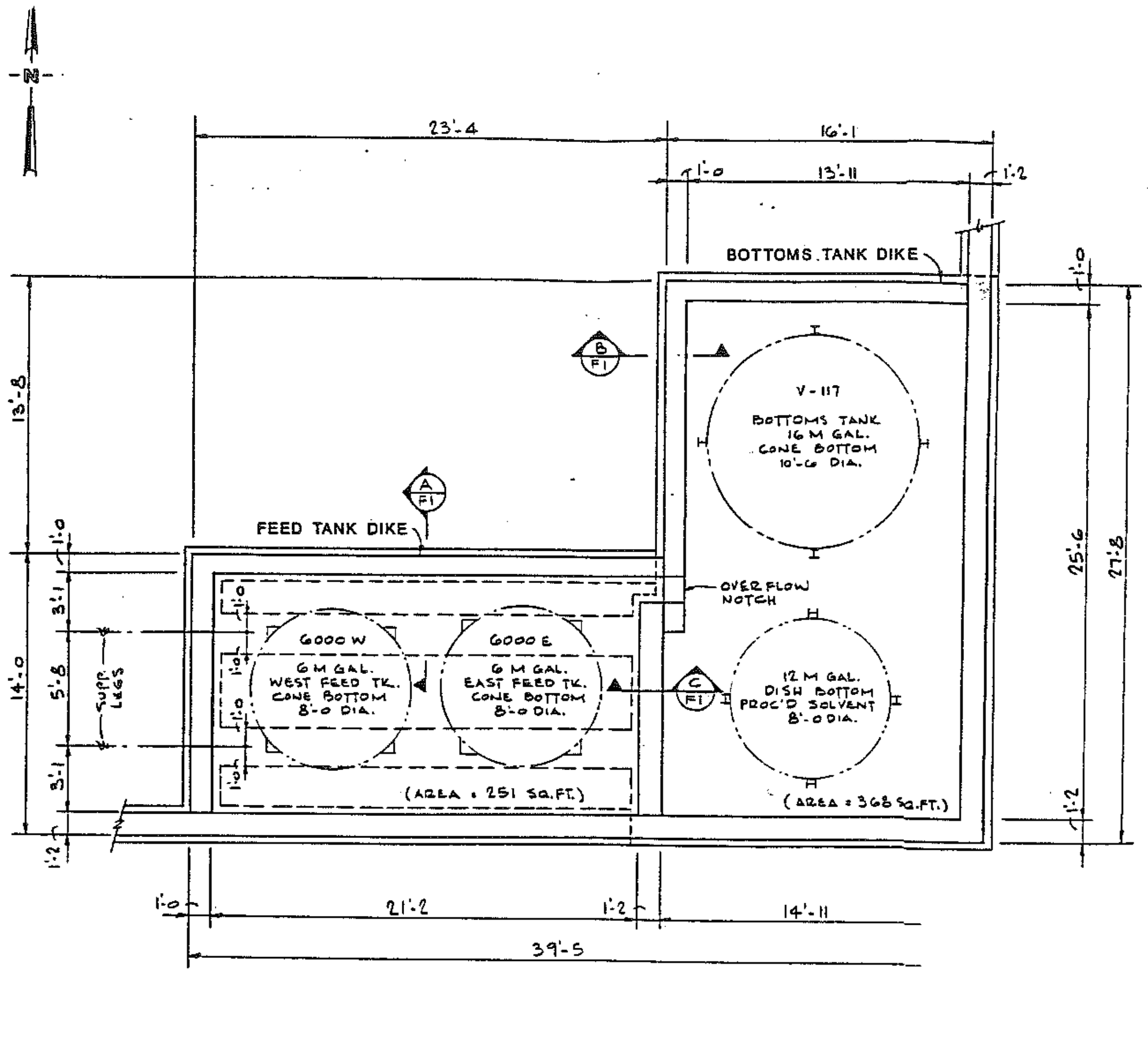
1. ALL CONCRETE CONSTRUCTION SHALL BE IN ACCORDANCE WITH THE LATEST EDITIONS OF ACI-301, ACI-302 AND ACI-318.
2. CONCRETE COMPRESSIVE STRENGTH SHALL BE 4000 PSI AT 28 DAYS AND SHALL BE AIR ENTRAINED.
3. REINFORCING STEEL SHALL BE ASTM A-615 GRADE 60 BAR, EXCEPT TIES AND STIRRUPS WHICH SHALL BE GRADE 40.
4. ALL REINFORCING SPLICES SHALL LAP A MINIMUM [illegible] BAR DIAMETERS.
5. PROVIDE CORNER BARS IN WALLS TO MATCH HORIZONTAL WALL REINFORCING 36 BAR DIAMETER LAP.
6. SET REINFORCING AS SHOWN. ALLOW 2 INCHES OF CLEARANCE BETWEEN REINFORCING AND FINISHED CONCRETE SURFACES. ALLOW [illegible] INCHES OF CLEARANCE BETWEEN THE REINFORCING AND CONCRETE WHERE CONCRETE IS AGAINST EARTH.
7. ANY SOIL IN A FOOTING EXCAVATION WHICH HAS BEEN EXPOSED TO RAIN SURFACE RUN-OFF, FROST OR FREEZING SHALL BE REMOVED PRIOR TO PLACING CONCRETE.
8. ALL EXCAVATIONS SHALL BE PROPERLY DE-WATERED.
9. CHAMFER ALL EXPOSED CONCRETE CORNERS 3/4 x 3/4.
10. BENCH MARK: ELEV. 982.58 "H" IN HYDRANT ON FIRE HYDRANT OPPOSITE HUKILL CHEMICAL.
11. REFERENCE DRAWING: FRANK B. KRAUSE & ASSOCIATES ORDER NO. 9615, SHEET 1 OF 1, DATED OCTOBER 6, 1988.

STATE OF OHIO STANLEY M. HAW 24218 REGISTERED PROFESSIONAL ENGINEER

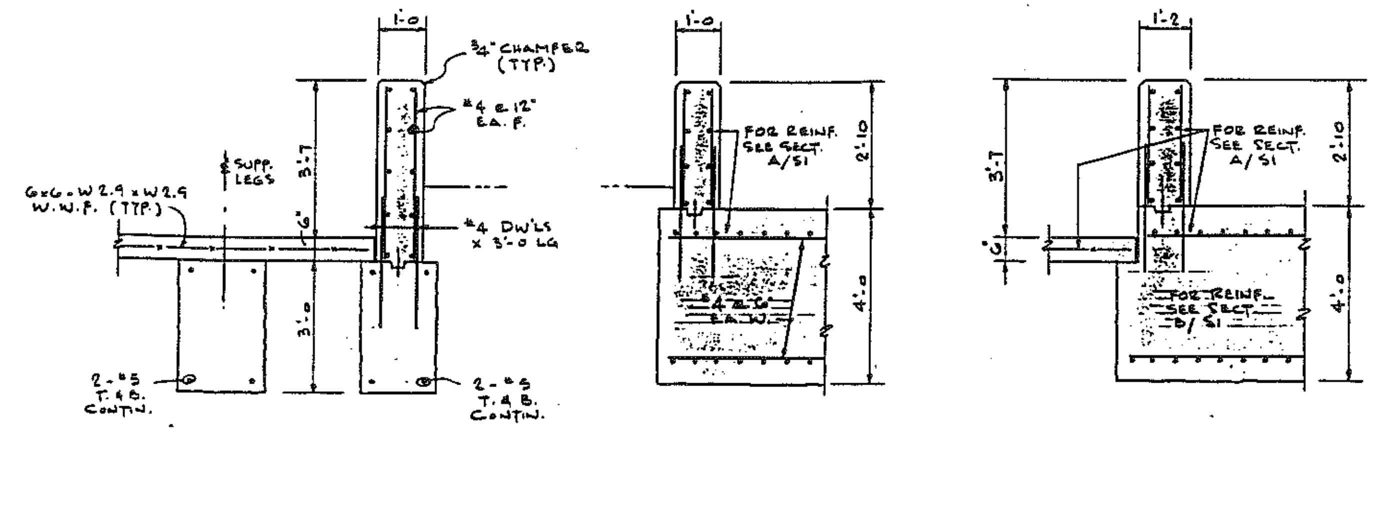
MARK	DESCRIPTION	BY	DATE	MARK	DESCRIPTION	BY	DATE	MARK	DESCRIPTION	BY	DATE
A	ORIGINAL ISSUE	MJM	1-17-92								

S. M. Haw Associates Professional Engineers Cleveland, Ohio	HUKILL CHEMICAL CORP.	DRAWN T. MULKA DATE 1-92; CHECKED DATE; PROJECT NO.	HAW ASSOCIATES
EAST PAD HAZARDOUS WASTE TANK DIKE	SCALE NOTED	ISSUE DATE 1-17-92	
DIKE PLAN SECTIONS & DETAILS	DRAWING NO 1294-F1	ISSUE A	

[14.1]



TANK DIKE FOUNDATION PLAN
1/4" = 1'-0



SECTION A/F1
1/2" = 1'-0

SECTION B/F1
1/2" = 1'-0

SECTION C/F1
1/2" = 1'-0

NOTE:

THIS DRAWING IS A COMPILATION OF INFORMATION OBTAINED BY FIELD MEASUREMENT AND FROM A SKETCH PREPARED BY MR. E. HUKILL ON OCTOBER 5, 1968.

IT IS BELIEVED TO BE A SUBSTANTIALLY TRUE REPRESENTATION OF THE DIKE, AS BUILT.

MARK	DESCRIPTION	BY	DATE
A	ORIGINAL ISSUE	EB	6-12-91

S. M. Haw Associates
Professional Engineers
Cleveland, Ohio

HUKILL CHEMICAL CORP.
KRICK ROAD BEDFORD, OHIO

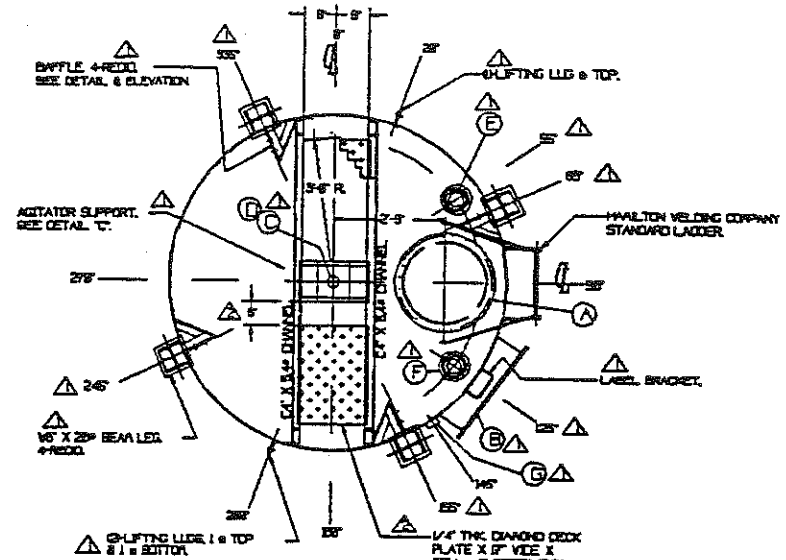
DRAWN EB DATE 5-91
CHECKED DATE
PROJECT NO.

FEED TANKS & BOTTOM TANKS
DIKE PLAN & SECTIONS

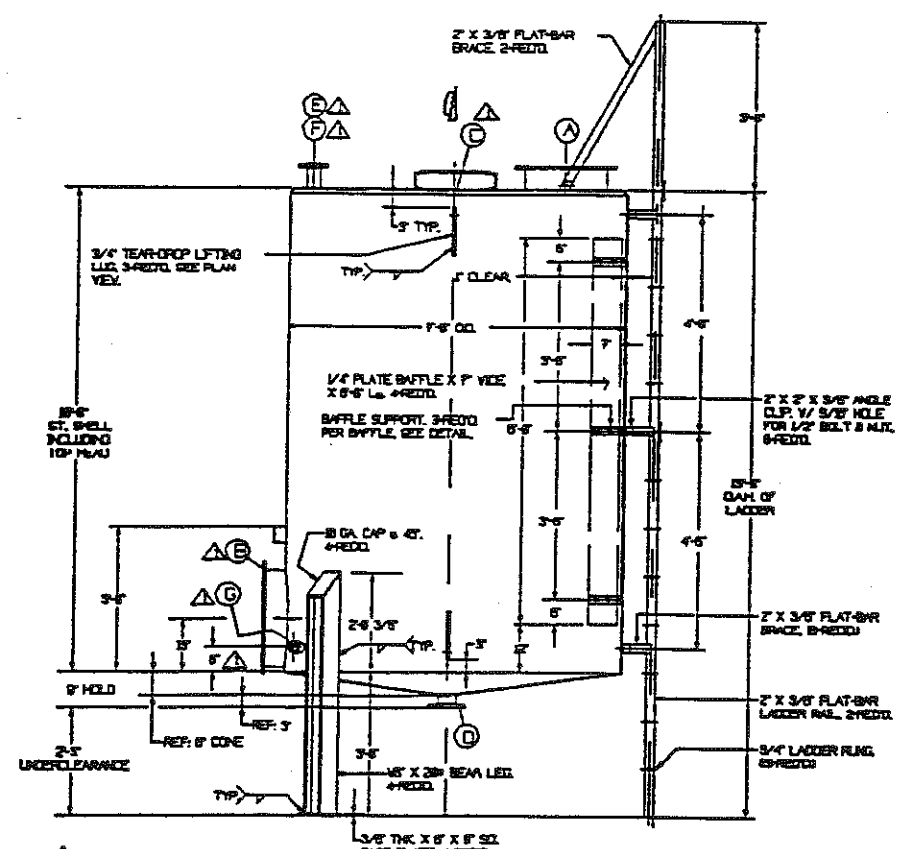
SCALE AS NOTED
ISSUE DATE 6-12-91
DRAWING NO 1700-F1
ISSUE A

142

Plan Sheet 11C



PLAN VIEW



NOTE: SEE PLAN VIEW FOR TRUE ORIENTATION OF FITTINGS.

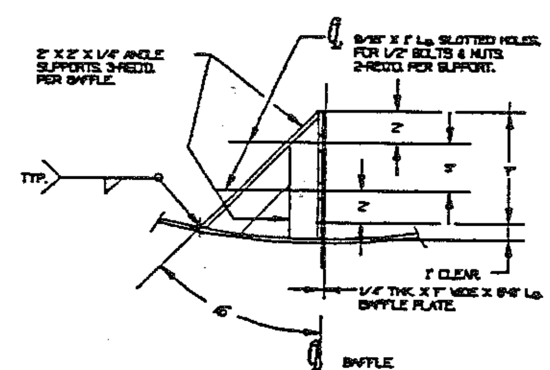
ELEVATION

3,000 gal. FEED TANKS (4)

\HAMILTON\3AFDTKS Rev. 4/4/95

Scale: 1/4" = 1'

ITEM	SIZE	RATING	TYPE	MATL.	PROJ. IN	PROJ. OUT	NOZZLE DESCRIPTION WEIGHT	WALL SZ	SIZE OD	WELD LEG DIA. NOZ TO SHL INWARD	OUTWARD	TYPE WLD	REMARKS	NOTES
A	28"	UL STYLE	MANWAY	C.S.	1/4"	AS SHWN.		.250"	24.500"			FILLET	SEE DETAIL "A"	ROOF MANWAY
B	24"	UL STYLE	MANWAY	C.S.	1/4"	AS SHWN.		.250"	24.000"			FILLET	SEE DETAIL "B"	SHELL MANWAY
C	5"	HOLE	CUT									NONE	SEE DETAIL "C"	IN TOP HEAD
D	4"	150#FLG.	S.O.R.F.	C.S.	8"	3"	STD.	.237"	4.500"			FILLET/GRV.	SEE DETAIL "D"	DRAIN
E	3"	150#FLG.	S.O.R.F.	C.S.	1/4"	6"	STD.	.216"	3.500"			FILLET	SEE DTL. "E & F"	
F	3"	150#FLG.	S.O.R.F.	C.S.	1/4"	6"	STD.	.216"	3.500"			FILLET	SEE DTL. "E & F"	
G	2"	STD.WT.	HF.CP.	C.S.	1/4"							FILLET	SEE DETAIL "G"	



BAFFLE DETAIL (4-REQ'D.)

NOTE: VERTICAL TANKS AND HORIZONTAL TANKS WITH SADDLES MAY REQUIRE SHIMMING AND GROUTING DURING INSTALLATION.

DESIGN DATA

1. MATERIAL :	ALLOWABLE STRESS	TYPE	THK.
TOP X RIGHT ___ HEAD : HRCS	N/A	F&F	7 GA.
BOTTOM X LEFT ___ HEAD: HRCS	N/A	CONE	7 GA.
SHELL : HRCS	N/A	PLATE	7 GA.
NOZZLES : A-53B	N/A	SEE-	SCH.
STRUCTURAL : A-36			
FLANGES: A-105			
COUPLINGS: STD. MERCHANT.			
GASKETS: 1/8" THK. TEFLON.			

2. VESSEL TO BE BUILT & LABELED ACCORDING TO ASME CODE SECTION VIII DIVISION 1. YES___ NO___ X
HEAT TREATMENT. YES___ NO___ X
DESIGN PRESSURE : ATMOS DESIGN TEMP : ___ AMBIENT
EXT. PRESSURE : N/A
HYDRO TEST PRESSURE : N/A
WELD PROCEDURE : N/A
70% JOINT EFFICIENCY. ______ XRAY REQ'D.
OTHER :

3. INTERIOR :
REMOVE WELD SLAG AND SPLATTER.

4. EXTERIOR :
SANDBLAST AND APPLY MAJESTIC # E-4525 (WHITE).

5a. ALL BOLT HOLES TO STRADDLE NATURAL C/L OF FITTINGS.
VESSEL NOT DESIGNED FOR PRE-MADE PIPING.
ALL FITTINGS TO BE PROTECTED FOR SHIPMENT.
TOLERANCES : SHELL DIAMETER OUT OF ROUNDNESS +/- 1%.
FLANGE LEVEL +/- 1%.

5b. CUSTOMER HAS THE RESPONSIBILITY TO VERIFY ALL DIMENSIONS ON THIS DRAWING.

6. VESSEL CAPACITY IN GALLONS : 3000 WT.:

7. NOTES :
A. QUANTITY: FOUR (4)-TANKS. T1, T2, T3 & T4.
B. TANKS TO BE AIR TESTED WITH WATER AND SOAP SUDS SOLUTION.
C. TANKS TO BEAR MANUFACTURERS LABEL ONLY.
D. TANKS TO INCLUDE ONE (1) EACH HAMILTON WELDING COMPANY STANDARD LADDER TO BE SHIPPED LOOSE FOR FIELD INSTALLATION BY OTHERS.
E. TANK TO INCLUDE TANK CALIBRATION CHART.

NO.	DESCRIPTION	DATE	NAME	
2	ADDED NOTE "E" & CHG. GASKET TYPE IN DETAIL "A".	[illegible]	A.D.	ALP
2	ADDED DIAMOND DECK PLATE TO TANK ROOF.	[illegible]	A.D.	ALP
1	CHG. MANWAY "B" TO A 24" UL. STYLE.	[illegible]	A.D.	ALP
1	CHG. GASKETS TO 1/8" THK. TEFLON.	[illegible]	A.D.	ALP
1	CHG. NOZZ'S. "E & F" TO 3" 150# FLG. NOZZLES.	[illegible]	A.D.	ALP
1	RELOCATE BEAM LEGS & BAFFLES.	[illegible]	A.D.	ALP
1	RELOCATE ALL NOZZS. PER REV. ONE.	[illegible]	A.D.	ALP
1	ADD AGITATOR SUPPORT PLATE & DETAIL "C".	[illegible]	A.D.	ALP

REVISIONS

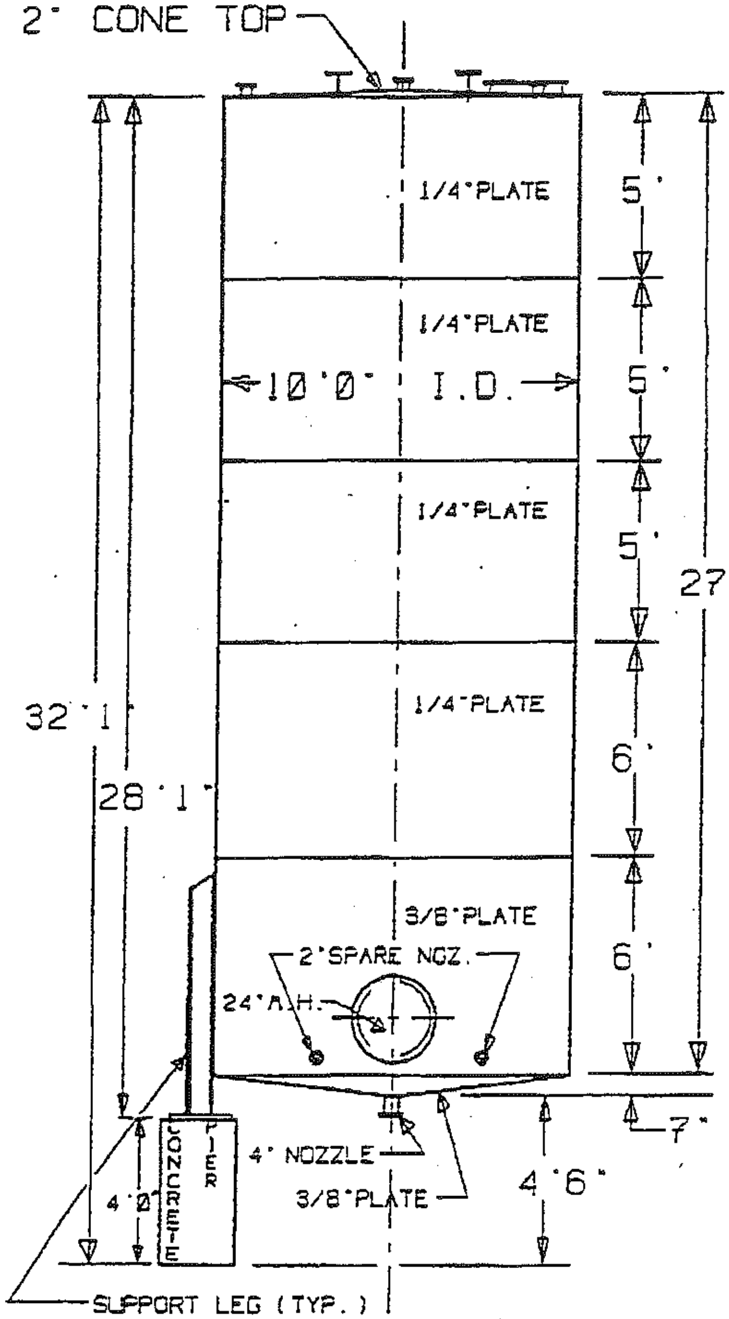
Hamilton Tanks

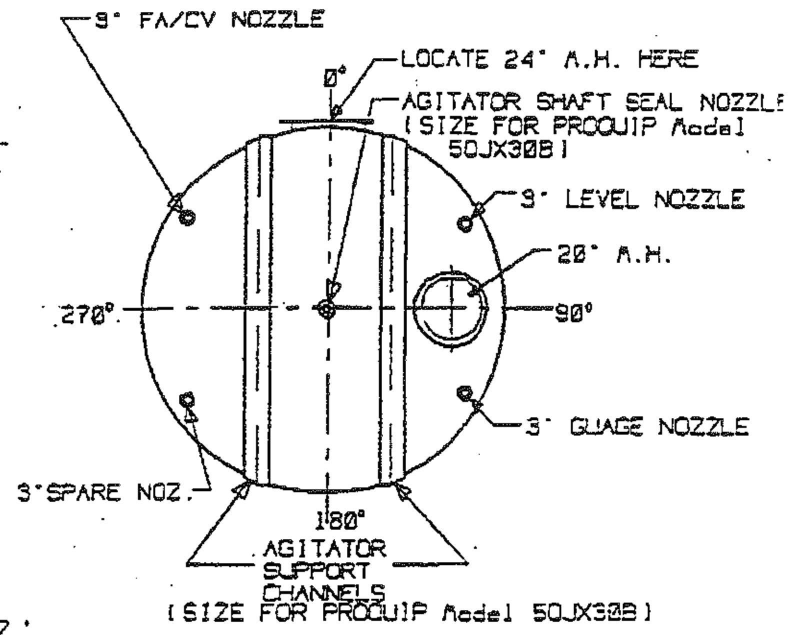
VESSEL DESCRIPTION :
3,000 GALLON VERTICAL STORAGE TANKS

CUSTOMER : HUKILL CHEMICAL CORPORATION | P.O. # 18218

DATE: 2-22-96 | SCALE: NONE | DWG. # HW910370 | NAME: AD | CHECKED BY: RICK

1.10a





TOP VIEW

NOTES:

15,000 GALLON WORKING CAPACITY, AGITATED STORAGE TANK FOR FLAMMABLE LIQUID STORAGE.

TANK TO BE OF CARBON STEEL CONSTRUCTION.

ALL NOZZLES TO BE SCHEDULE 80 CARBON STEEL.
ALL NOZZLES TO BE 3" LONG UNLESS NOTED.

AGITATOR NOZZLE TO MATCH THE VENDOR'S SEAL DESIGN FOR VAPOR TIGHT CONSTRUCTION.

AGITATOR/MOTOR WEIGHT IS 3,700 POUNDS.

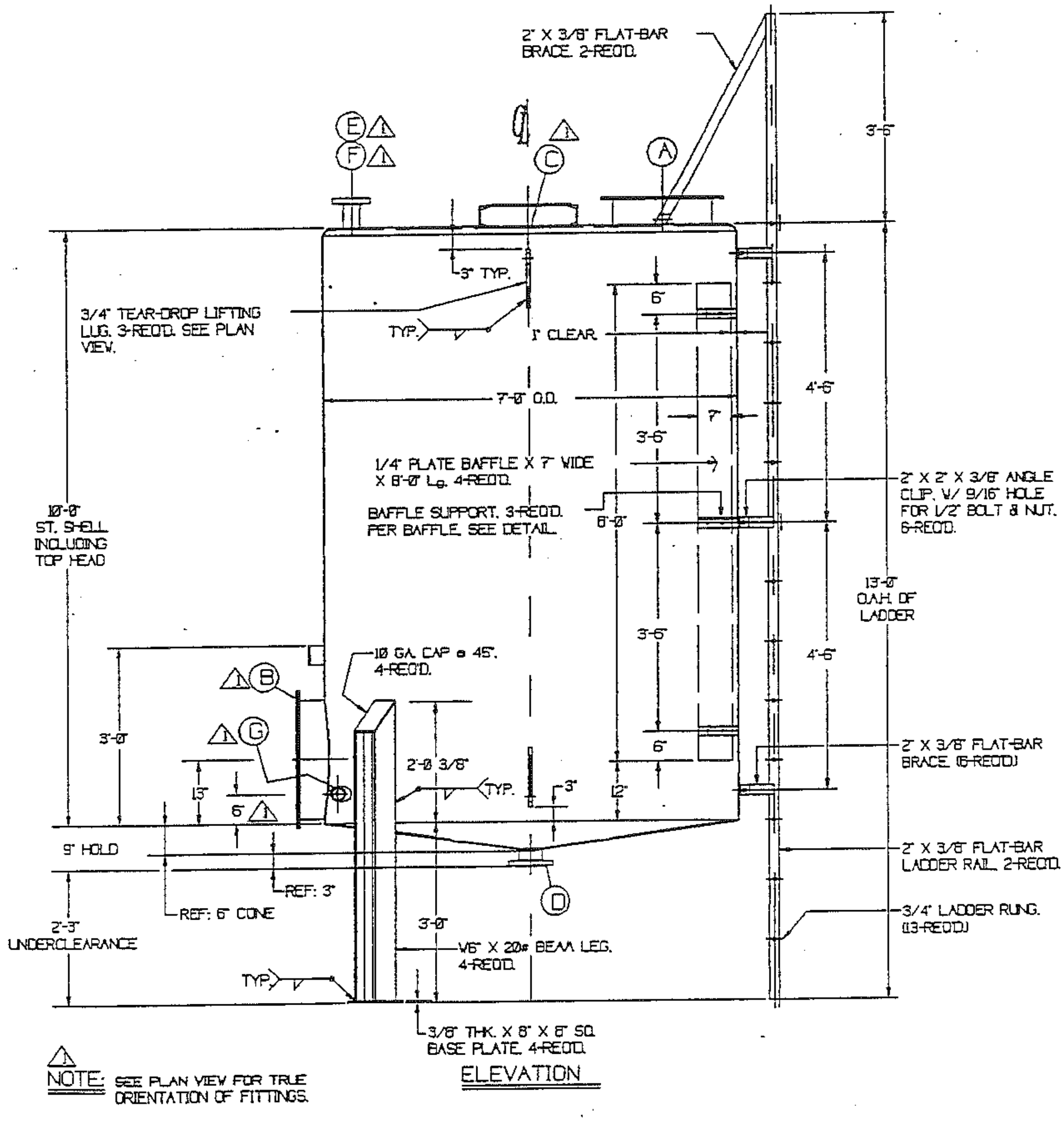
DESIGN SUPPORT LEGS FOR TANK AND AGITATOR WEIGHT PLUS 15,900 GAL. OF 84 LB./CU.FT. LIQUID.
84

PROVIDE OSHA REQUIRED RAILING AROUND THE TOP OF THE TANK WITH ENTRANCE AT 270° POINT FOR STAIRWAY ATTACHMENT.

15 M FUELS TANK

HUKILL CHEMICAL CORP
\HWFUELS\15MTANK.DWG
Rev. 3/4/92
Scale: 3/16" = 1'

1.9b

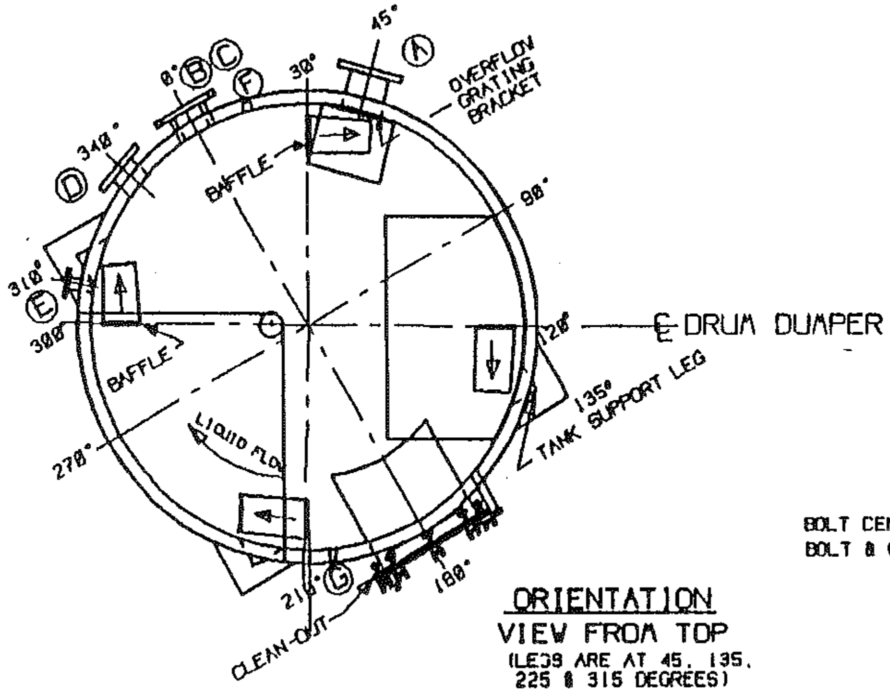


ELEVATION

3.000 gal. FEED TANKS (4)

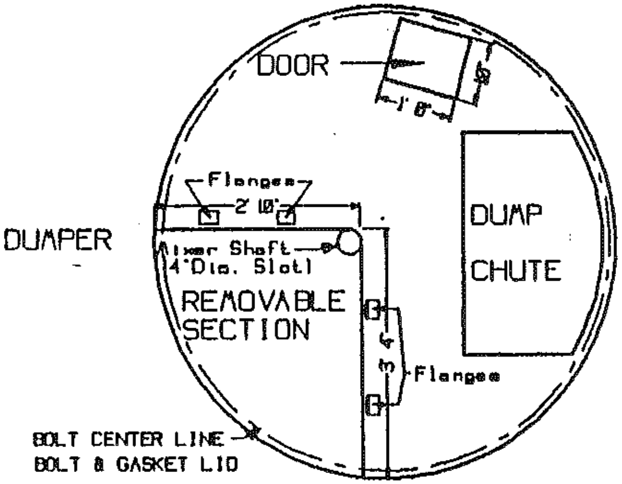
\HAMILTON\3MFDTKS Rev. 4/4/95

FIGURE 1

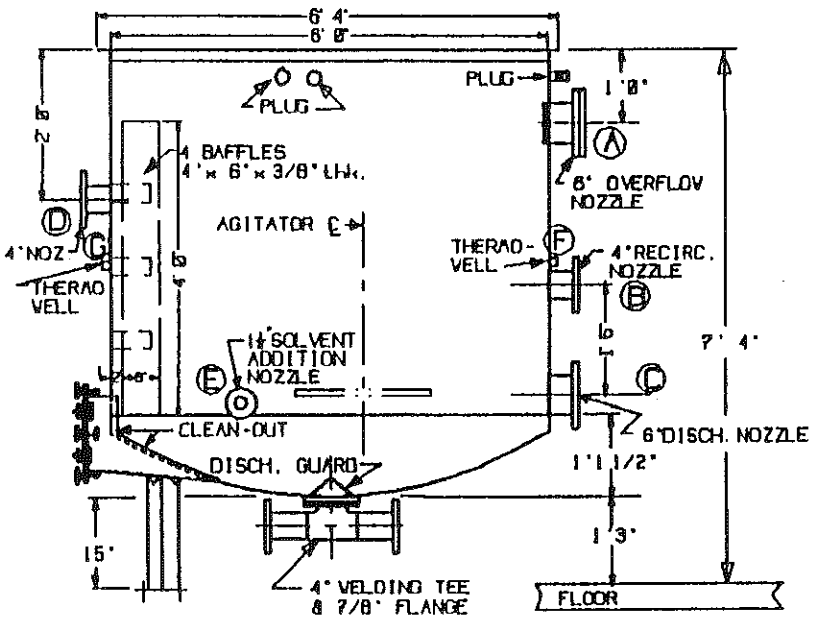


ORIENTATION
VIEW FROM TOP
(LEGS ARE AT 45, 135, 225 & 315 DEGREES)

TOP VIEW



COVER OPENINGS



ELEVATION

PIPE IDENTIFICATION
A = 6" Dia. X 4" Long
B = 4" Dia. X 4" Long
C = 6" Dia. X 4" Long
D = 4" Dia. X 4" Long
E = 1 1/2" X 4" Long
F = 1" Half Coupling
G = 1" Half Coupling

DISPERSER TANK - 1,000 gal.

HUKILL CHEMICAL CORPORATION
7013 KRICK ROAD, BEDFORD, OH 44146
\PARTB-9\DISPERTK.GCD Rev. 7/27/94
Scale: 3/8" = 1'

Drawing of

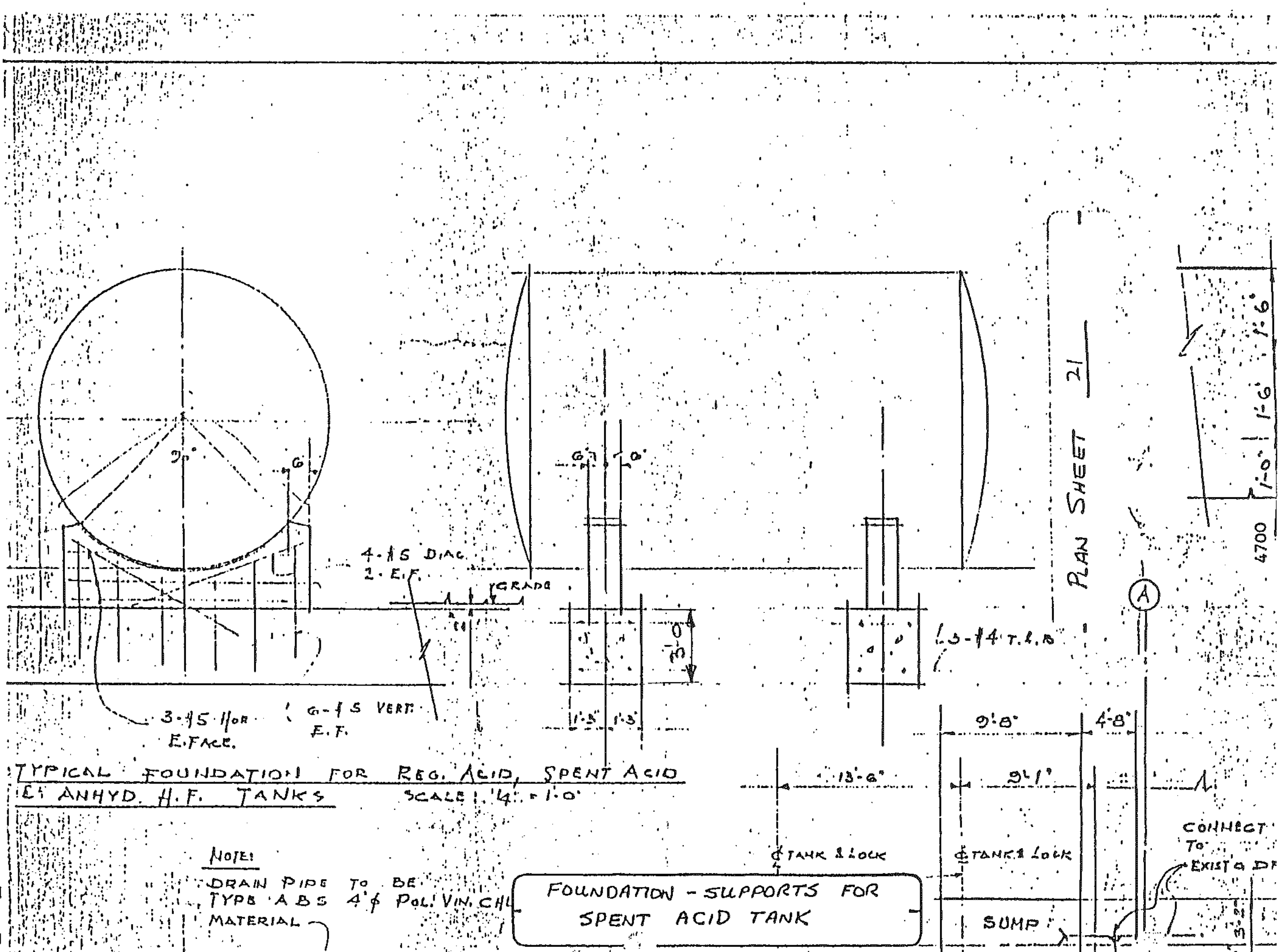
Spent Acid Tank

is located in

Part B
Application

Plan Sheets - Book 2
Revision 5, 1/92

Plan Sheet 19



TYPICAL FOUNDATION FOR REG. ACID, SPENT ACID
& ANHYD. H.F. TANKS
SCALE 1/4" = 1'-0"
NOTE:
DRAIN PIPE TO BE TYPE ABS 4" ϕ POL. VIN. CHL MATERIAL
FOUNDATION - SUPPORTS FOR SPENT ACID TANK
PLAN SHEET 21
4-#5 DIAG. 2 - E.F.
GRADE
3-#5 HOR E.FACE.
6-#5 VERT. E.F.
3-#4 T.&B.
℄ TANK & LOCK
℄ TANK & LOCK
SUMP
CONNECT TO EXIST'G DR
4700
13'-6"
9'-8"
4'-8"
9'-1"
1'-3"
1'-3"
1'-0"
1'-6"
1'-6"
90°
6"

vessel, and signed by the fabricator and by the authorized inspector. Copies of these reports are always sent to the vessel owner. If the vessel is to be registered with the National Board, the board receives two copies of each (see also p. 6-92), one of which it forwards to the Code authority in the state where the vessel will be installed.

Materials of Construction. Subsection C, Requirements Pertaining to Classes of Materials, deals with allowable stresses and other requirements which are dependent upon the material. With certain exceptions, it requires that all materials subject to stress in Code vessels shall conform to one of the specifications given in Section II (Material Specifications) of the Boiler and Pressure Vessel Code. Subsection C is divided into the following parts:

UCS—Carbon and low-alloy steels
UNF—Nonferrous materials
UHA—High-alloy steels
UCI—Cast iron
UCL—Integrally clad plate or corrosion-resistant linings
UCD—Cast ductile iron
UHT—Ferritic steels with properties enhanced by heat treatment

Part UNF tabulates some mechanical and physical properties that are not readily found elsewhere.

Tables 6-57 through 6-59 show the allowable stresses at several temperatures for some of the more frequently used materials in Parts UCS, UNF, and UHA. Materials are not approved for temperatures outside the ranges shown in the Code.

Fabrication Methods. Subsection B, Requirements Pertaining to Methods of Fabrication of Pressure Vessels, is divided into the following parts:

UW—Welded vessels
UR—Riveted vessels
UF—Forged vessels
UB—Brazed vessels

Welding is almost universally employed for fabrication of pressure vessels. Forged vessels are generally used for high pressures where shell thickness becomes too great for rolled and welded plate construction. Brazing is used mainly for small vessels in quantity production, although the Code does not place any limit on their size.

Welded vessels (discussed in Part UW) may be fabricated from any Code-approved materials that are proved to be of good weldable quality. The welding procedure must be qualified in accordance with Section IX. Section IX also requires that each welder pass qualification tests for each particular type of welding or welding machine operation in which he is involved. Usually, steels with less than 0.35 per cent carbon can be welded without difficulty.

Table 6-57. Maximum Allowable Stress Values in Tension for Carbon and Low-alloy Steels

Values in pounds per square inch

A.S.M.E. Specification No.	Grade	Nominal composition	Spec. min. tensile strength	For temperatures not exceeding °F. −20 to 650	700	800	900	1000	1100	1200
Plates										
Carbon Steel										
SA515	55	C-Si	55,000	$\boxed{13,700}$	13,200	10,200	6,500	2,500		
SA515	70	C-Si	70,000	17,500	16,600	12,000	6,500	2,500		
SA516	55	C-Si	55,000	13,700	13,200	10,200	6,500	2,500		
SA516	70	C-Si	70,000	$\boxed{17,500}$	16,600	12,000	6,500	2,500		
SA285	A	....	45,000	11,200	11,000	9,000	6,500			
SA285	B	....	50,000	12,500	12,100	9,600	6,500			
SA285	C	....	55,000	13,700	13,200	10,200	6,500			
Low-alloy Steel										
SA202	A	Cr-Mn-Si	75,000	18,700	17,700	12,600	6,500	2,500		
SA202	B	Cr-Mn-Si	85,000	21,200	19,800	12,800	6,500	2,500		
SA387	D*	2¼ Cr-1 Mo	60,000	15,000	15,000	15,000	13,100	7,800	4,200	1,600
Seamless Pipes and Tubes										
Carbon Steel										
SA53	A	....	48,000	12,000	11,600	9,300	6,500			
SA53	B	....	60,000	15,000	14,300	10,800	6,500			
Low-alloy Steel										
SA213	T22	2¼ Cr-1 Mo	60,000	15,000	15,000	15,000	13,100	7,800	4,200	1,600
Forgings										
Carbon Steel										
SA105	I	....	60,000	15,000	14,300	10,800	6,500	2,500		
SA105	II	....	70,000	17,500	16,600	12,000	6,500	2,500		
Low-alloy Steel										
SA182	F22	2¼ Cr-1 Mo	70,000	17,500	17,500	17,500	14,000	7,800	4,200	1,600
SA372	IV	0.25 Mo	105,000	26,200 to 24,600 (when normalized or normalized and tempered)						
Castings										
Carbon Steel										
SA216	WCA	....	60,000	15,000	14,300	10,800	6,500	2,500		
SA216	WCB	....	70,000	17,500	16,600	12,000	6,500	2,500		
Low-alloy Steel										
SA217	WC9	2¼ Cr-1 Mo	70,000	17,500	17,500	17,000	14,000	7,800	4,200	1,600
Bolting										
Carbon Steel										
SA307	B	....	55,000	7,000	(not permitted above 450°F.)					
Low-alloy Steel										
SA193	B7†	1 Cr-0.2 Mo	....	25,000	25,000	21,000	12,500	4,500		
SA193	B16†	1 Cr-0.5 Mo	....	25,000	25,000	25,000	20,500	11,000	2,700	

*Annealed. †Under 2½ in. diameter.

2.1

Table 6-58. Maximum Allowable Stress Values in Tension for Aluminum and Aluminum-alloy Products

Values in pounds per square inch

A.S.T.M. alloy designation	Temper	Thickness, in.	Specified minimum tensile strength	Specified minimum yield strength	For temperatures not exceeding °F. 100	150	200	250	300	350	400
Sheet and Plate: A.S.M.E. Specification No. SB-209											
1060	0	0.051–3.000	8,000	2,500	1,600	1,600	1,600	1,400	1,200	1,000	800
	H12	0.051–2.000	11,000	9,000	2,700	2,700	2,600	2,300	2,000	1,800	1,100
	H14	0.051–1.000	12,000	10,000	3,000	3,000	3,000	2,900	2,600	1,800	1,100
	H112	0.250–0.499	11,000	7,000	2,700	2,600	2,400	2,000	1,800	1,600	1,000
	H112	0.500–1.000	10,000	5,000	2,500	2,400	2,100	1,900	1,600	1,400	1,000
	H112	1.001–3.000	9,000	4,000	2,200	2,100	1,900	1,700	1,400	1,000	800
5052	0	0.051–3.000	25,000	9,500	6,200	6,200	6,200	6,200	5,600	4,100	2,300
	H32	0.051–2.000	31,000	23,000	7,700	7,700	7,700	7,500	6,100	4,100	2,300
	H34	0.051–1.000	34,000	26,000	8,500	8,500	8,500	8,400	6,100	4,100	2,300
	H112	0.250–0.499	28,000	16,000	7,000	7,000	7,000	7,000	6,100	4,100	2,300
	H112	0.500–3.000	25,000	9,500	6,200	6,200	6,200	6,200	6,000	4,100	2,300
5456	0	0.051–1.500	42,000	19,000	10,500	10,500					
	0	1.501–3.000	41,000	18,000	10,200	10,200					
	H321	0.188–1.250	46,000	33,000	11,500	11,500					
	H321	1.251–1.500	44,000	31,000	11,000	11,000					
	H321	1.501–3.000	41,000	29,000	10,200	10,200					
Rods, Bars, and Shapes: A.S.M.E. Specification No. SB-221											
1060	0, H112	All	8,500	2,500	1,600	1,600	1,600	1,400	1,200	1,000	800
Drawn Seamless Tube: A.S.M.E. Specification SB-210											
1060	0, H112	0.010-0.500	8,500	2,500	1,600	1,600	1,600	1,400	1,200	1,000	800
	H14	0.010-0.500	12,000	10,000	3,000	3,000	3,000	2,900	2,600	1,800	1,100
Bolting Materials: A.S.M.E. Specification No. SB-211											
2014	T6	0.125–8.000	65,000	55,000	13,000	12,200	11,600	10,400	7,200	4,400	3,000

Table 6-59. Maximum Allowable Stress Values in Tension for High-alloy Steels*

Values in pounds per square inch

A.S.M.E. Specification No.	Grade	Nominal composition	Specified minimum tensile strength	For temperatures not exceeding °F. −20 to 100	200	400	700	900	1000	1100	1200	1300	1400	1500
Plate Steels														
SA-240	304	18 Cr-8 Ni	75,000	18,700	15,600	12,900	11,000	10,100	9,700	8,800	6,000	3,700	2,300	1,400
SA-240	304L†	18 Cr-8 Ni	70,000	15,600	13,300	10,000	9,300							
SA-240	310S	25 Cr-20 Ni	75,000	18,700	16,900	14,900	12,700	11,600	9.800	5,000	2,500	700	300	200
SA-240	316	16 Cr-12 Ni-2 Mo	75,000	18,700	16,100	13,300	11,300	10,800	10,600	10,300	7,400	4,100	2,200	1,700
SA-240	410	13 Cr	65,000	16,200	15,400	14,400	13,100	10,400	6,400	2,900	1,000			
Pipes and Tubes—Welded														
SA-249	TP304	18 Cr-8 Ni	75,000	15,900	13,300	11,000	12,000	11,500	10,600	7,400	4,600	2,900	1,700	1,000
SA-268	TP410	13 Cr	60,000	12,700	12,100	11,300	10,200							
Bolting														
SA-193	B8	18 Cr-8 Ni	75,000	15,000	13,300	10,900	8,600	7,500	7,000	6,300	4,500	2,400	1,400	750
SA-193	B6(410)	13 Cr	110,000	20,000	19,000	17,700	16,100	11,000						

*The Code gives several sets of stress values dependent on specific conditions (see Code Table UHA-23).

†9000 lb./sq. in. at 800°F.

Post-weld heat treatment (usually stress relief) is required for some conditions, such as thick plate, low-temperature service, high carbon, and highly toxic contents.

The Code does not permit any welding to be done when the metal is below 0°F. Between 0° and 32°F., the metal adjacent to the weld must be heated to at least 60°F. before welding is started. It recommends that no welding be done when the surfaces are wet or covered with ice, when snow is falling, or when exposed to high winds unless the work is adequately protected. Welding surfaces must also be free of grease, dirt, and slag.

The types of welds used for most longitudinal and circumferential joints in pressure vessels are shown in Fig. 6-138. Table 6-60 shows allowable welded-joint efficiencies for the three welds shown in Fig. 6-138. Weld efficiency is the ratio of the allowable stress in the

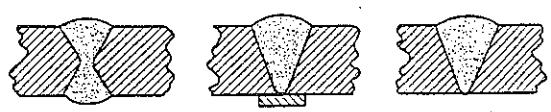


Fig. 6-138. Weld types: (*a*) Double-welded butt joint, back-chipped before welding second side. (*b*) Single-welded butt joint, with backing strip which may or may not be removed. (*c*) Single-welded butt joint, no backing strip (permitted only for certain circumferential welds).

Structural Assessment of a Hazardous Waste Storage Tank
for Hukill Chemical Company

7 Tank Dike System - Tanks V-114 thru V-614
Exhibit D-2

Summary of Minimum Tank Wall Measurements
Professional Service Industries, Inc.
Report No. 138-48041-001 - Dated June, 1994

	V-114	V-214	V-314	V-414	V-514	V-614
PSI Report Sheet	[3.2]	[3.2]	[3.3]	[3.4]	[3.4]	[3.5]
Top 1	225	266	265	267	265	253
Top 2	-	262	262	249	250	242
Upper 1	225	259	256	244	253	254
Upper 2	238	266	266	262	252	250
Lower 1	276	297	286	276	274	272
Lower 2	252	293	282	282	270	281
Bottom 1	260	299	285	289	276	282
Bottom 2	263	293	271	280	276	292

☐ = Critical Wall Thickness

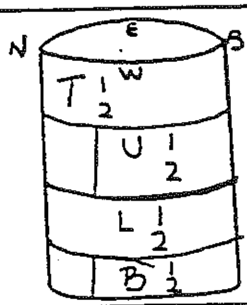
Professional Service Industries, Inc.

TESTED FOR: Hukill Chemical Corporation
7013 Krick Road
Bedford, Ohio 44146

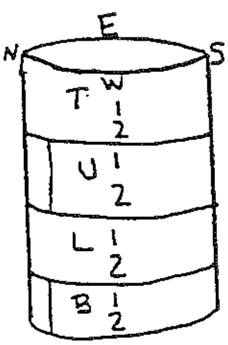
PROJECT: Tank Wall Thickness Measurements

DATE: June 1994

OUR REPORT NO.: 138-48041-001



Note: On Vertical tanks - 0° = North On Horizontal tanks - 0° = Top V-114 57-14F	NORTH 0°/360°	NORTH EAST 45°	EAST 90°	SOUTH EAST 135°	SOUTH 180°	SOUTH WEST 225°	WEST 270°	NORTH WEST 315°
TOP	260	226	226	270	263	244	225	270
UPPER	240 250		225 239		244 238		239 246	
LOWER	284 270		276 252		287 264		278 270	
BOTTOM	282 264		260 268		278 278		267 263	



Note: On Vertical tanks - 0° = North On Horizontal tanks - 0° = Top V214 58-14F	NORTH 0°/360°	NORTH EAST 45°	EAST 90°	SOUTH EAST 135°	SOUTH 180°	SOUTH WEST 225°	WEST 270°	NORTH WEST 315°
TOP	271	265	273	274 277			266	266 262
UPPER	263	274	267 268	273	273 266		259 284	261
MIDDLE								
LOWER	298 296		297 293		298 307		308 311	
BOTTOM	299 296		309 293		308 297		306 298	
CONE								

Respectfully submitted,
PROFESSIONAL SERVICE INDUSTRIES, INC.
C. Hubbuch

5555 Canal Road • Cleveland, OH 44125 • Phone: 216/447-1335 • Fax: 216/642-7008

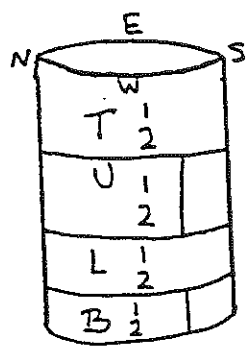
Professional Service Industries, Inc.

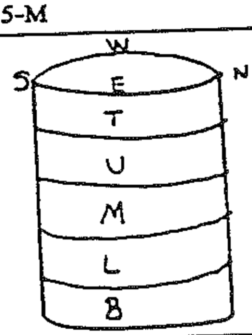
TESTED FOR: Hukill Chemical Corporation
7013 Krick Road
Bedford, Ohio 44146

PROJECT: Tank Wall Thickness Measurements

DATE: June 1994

OUR REPORT NO.: 138-48041-001

Note: On Vertical tanks - 0° = North On Horizontal tanks - 0° = Top V314 59-14-F		NORTH 0°/360°	NORTH EAST 45°	EAST 90°	SOUTH EAST 135°	SOUTH 180°	SOUTH WEST 225°	WEST 270°	NORT WEST 315°
 	TOP	265 280		270 262		280 269		297 266	
	UPPER	256 281		280 278		280 266		303 269	
	MIDDLE								
	LOWER	289 282		287 289		286 285		294 288	
	BOTTOM	285 271		286 284		305 300		292 288	
	CONE								

Note: On Vertical tanks - 0° = North On Horizontal tanks - 0° = Top 13-15-M		NORTH 0°/360°	NORTH EAST 45°	EAST 90°	SOUTH EAST 135°	SOUTH 180°	SOUTH WEST 225°	WEST 270°	NOR WES 315°
 	TOP	251		249		258		254	
	UPPER	248		249		257		252	
	MIDDLE	247		253		252		253	
	LOWER	250		257		246		248	
	BOTTOM	387		386		379		379	
	CONE								

Respectfully submitted,
PROFESSIONAL SERVICE INDUSTRIES, INC.
C. Hubbuch

5555 Canal Road • Cleveland, OH 44125 • Phone: 216/447-1335 • Fax: 216/642-7008

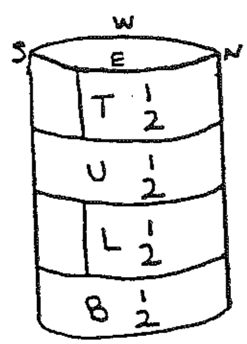
Professional Service Industries, Inc.

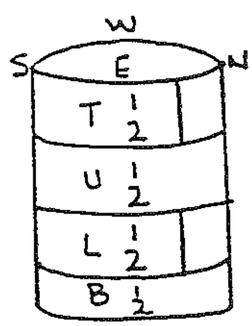
TESTED FOR: Hukill Chemical Corporation
7013 Krick Road
Bedford, Ohio 44146

PROJECT: Tank Wall Thickness Measurements

DATE: June 1994

OUR REPORT NO.: 138-48041-001

Note: On Vertical tanks - 0° = North On Horizontal tanks - 0° = Top V-414 60-14-F		NORTH 0°/360°	NORTH EAST 45°	EAST 90°	SOUTH EAST 135°	SOUTH 180°	SOUTH WEST 225°	WEST 270°	NORT WEST 315°
	TOP	274 249		277 263		276 257		267 258	
	UPPER	269 270		267 262		276 286		244 263	
	MIDDLE								
	LOWER	292 285		298 282		276 293		276 282	
	BOTTOM	289 282		299 280		289 297		299 280	
	CONE								

Note: On Vertical tanks - 0° = North On Horizontal tanks - 0° = Top V-514 61-14-F		NORTH 0°/360°	NORTH EAST 45°	EAST 90°	SOUTH EAST 135°	SOUTH 180°	SOUTH WEST 225°	WEST 270°	NOR WES 315°
	TOP	274 254		265 250		270 256		268 252	
	UPPER	264 253		265 252		255 289		253 256	
	MIDDLE								
	LOWER	288 270		274 281		276 298		283 274	
	BOTTOM	276 286		280 276		288 296		296 278	
	CONE								

Respectfully submitted,
PROFESSIONAL SERVICE INDUSTRIES, INC.
C. Hubbuch

5555 Canal Road • Cleveland, OH 44125 • Phone: 216/447-1335 • Fax: 216/642-7008

Professional Service Industries, Inc.

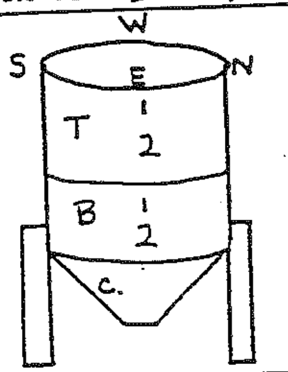
TESTED FOR: Hukill Chemical Corporation
7013 Krick Road
Bedford, Ohio 44146

PROJECT: Tank Wall Thickness Measurements

DATE: June 1994

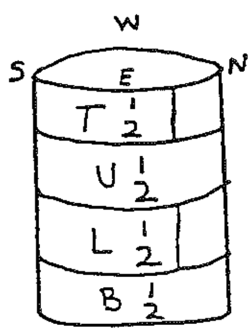
OUR REPORT NO.: 138-48041-001

Note: On Vertical tanks - 0° = North
On Horizontal tanks - 0° = Top
53-5.6-CL *East Feed Tank*



	NORTH 0°/360°	NORTH EAST 45°	EAST 90°	SOUTH EAST 135°	SOUTH 180°	SOUTH WEST 225°	WEST 270°	NORTH WEST 315°
TOP	263 267		268 272		258 258		262 261	
UPPER								
MIDDLE								
LOWER								
BOTTOM	269 268		265 266		265 256		267 259	
CONE	250		252		257		251	

Note: On Vertical tanks - 0° = North
On Horizontal tanks - 0° = Top
V-614 62-14-F



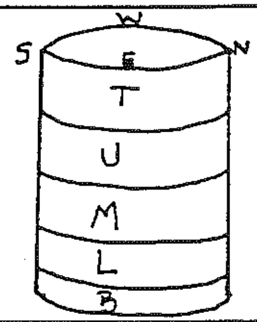
	NORTH 0°/360°	NORTH EAST 45°	EAST 90°	SOUTH EAST 135°	SOUTH 180°	SOUTH WEST 225°	WEST 270°	NORTH WEST 315°
TOP	256 243		276 242		270 249		253 243	
UPPER	266 260		264 252		262 258		254 250	
MIDDLE								
LOWER	287 289		282 284		274 285		272 281	
BOTTOM	287 304		284 292		288 298		282 295	
CONE								

Respectfully submitted,
PROFESSIONAL SERVICE INDUSTRIES, INC.
C. Hubbuch

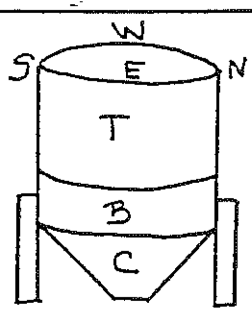
psi

Professional Service Industries, Inc.

TESTED FOR:	Hukill Chemical Corporation 7013 Krick Road Bedford, Ohio 44146	PROJECT:	Tank Wall Thickness Measurements
DATE:	June 1994	OUR REPORT NO.:	138-48041-001



Note: On Vertical tanks - 0° = North On Horizontal tanks - 0° = Top V-120 SS 56-20-CL		NORTH 0°/360°	NORTH EAST 45°	EAST 90°	SOUTH EAST 135°	SOUTH 180°	SOUTH WEST 225°	WEST 270°	NORTH WEST 315°
	TOP	207		202		213		202	
	UPPER	212		211		210		208	
	MIDDLE	217		203		210		212	
	LOWER	204		204		202		206	
	BOTTOM	208		205		205		214	
	CONE								



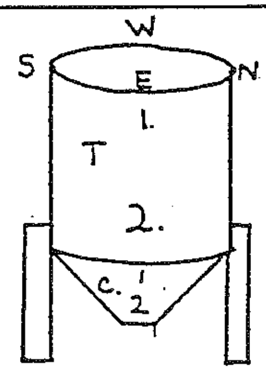
Note: On Vertical tanks - 0° = North On Horizontal tanks - 0° = Top 1500 Cone 75-1.5-F		NORTH 0°/360°	NORTH EAST 45°	EAST 90°	SOUTH EAST 135°	SOUTH 180°	SOUTH WEST 225°	WEST 270°	NORTH WEST 315°
	TOP	170		160		169		176	
	UPPER								
	MIDDLE								
	LOWER								
	BOTTOM	146		142		145		152	
	CONE	151		128		130		117	

Respectfully submitted,
PROFESSIONAL SERVICE INDUSTRIES, INC.
C. Hubbuch

5555 Canal Road • Cleveland, OH 44125 • Phone: 216/447-1335 • Fax: 216/642-7008

Professional Service Industries, Inc.

TESTED FOR:	Hukill Chemical Corporation 7013 Krick Road Bedford, Ohio 44146	PROJECT:	Tank Wall Thickness Measurements
DATE:	June 1994	OUR REPORT NO.:	138-48041-001

Note: On Vertical tanks - 0° = North On Horizontal tanks - 0° = Top 4000 Cone 76-4-CL		NORTH 0°/360°	NORTH EAST 45°	EAST 90°	SOUTH EAST 135°	SOUTH 180°	SOUTH WEST 225°	WEST 270°	NOR WES 315°
	TOP	245 242		237 240		244 223		242 224	
	UPPER								
	MIDDLE								
	LOWER								
	BOTTOM								
	CONE	282 329		324 320		324 340		323 324	

Respectfully submitted,
PROFESSIONAL SERVICE INDUSTRIES, INC.
C. Hubbuch

5555 Canal Road • Cleveland, OH 44125 • Phone: 216/447-1335 • Fax: 216/642-7008

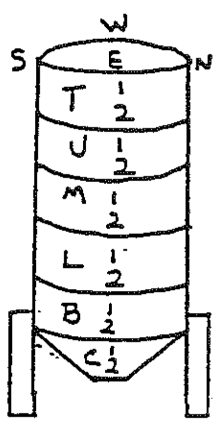
Professional Service Industries, Inc.

TESTED FOR: Hukill Chemical Corporation
7013 Krick Road
Bedford, Ohio 44146

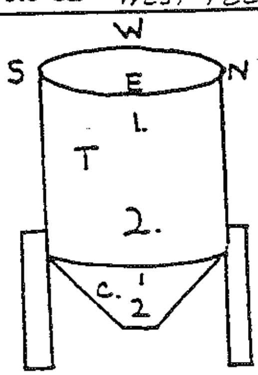
PROJECT: Tank Wall Thickness Measurements

DATE: June 1994

OUR REPORT NO.: 138-48041-001



Note: On Vertical tanks - 0° = North On Horizontal tanks - 0° = Top V117 55-16-CL	NORTH 0°/360°	NORTH EAST 45°	EAST 90°	SOUTH EAST 135°	SOUTH 180°	SOUTH WEST 225°	WEST 270°	NORTH WEST 315°
TOP	214 234		221 235		220 224		211 228	
UPPER	233 248		246 250		236 252		248 249	
MIDDLE								
LOWER	249 251		258 254		254 256		250 244	
BOTTOM	251 248		250 251		247 249		249 252	
CONE	244 242		250 260		251 267		248 252	



Note: On Vertical tanks - 0° = North On Horizontal tanks - 0° = Top 52-5.6-CL *West Feed Tank*	NORTH 0°/360°	NORTH EAST 45°	EAST 90°	SOUTH EAST 135°	SOUTH 180°	SOUTH WEST 225°	WEST 270°	NORTH WEST 315°
TOP	263 258		268 265		256 260		270 268	
UPPER								
MIDDLE								
LOWER								
BOTTOM	260 257		262 257		262 257		260 254	
CONE	263		253		250		265	

Respectfully submitted,
PROFESSIONAL SERVICE INDUSTRIES, INC.
C. Hubbuch

5555 Canal Road • Cleveland, OH 44125 • Phone: 216/447-1335 • Fax: 216/642-7008

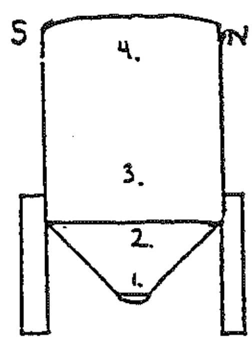
[psi] Professional Service Industries, Inc.

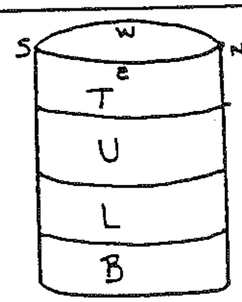
TESTED FOR: Hukill Chemical Corporation
7013 Krick Road
Bedford, Ohio 44146

PROJECT: Tank Wall Thickness Measurements

DATE: June 1994

OUR REPORT NO.: 138-48041-001

Note: On Vertical tanks - 0° = North On Horizontal tanks - 0° = Top V-6000-C 16-6-M		NORTH 0°/360°	NORTH EAST 45°	EAST 90°	SOUTH EAST 135°	SOUTH 180°	SOUTH WEST 225°	WEST 270°	NORT WEST 315°
	TOP	262 256		258 266		240 238		268 243	
	UPPER								
	MIDDLE								
	LOWER								
	BOTTOM								
	CONE	256 252		248 249		250 252		240 250	

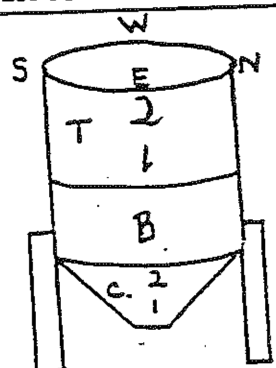
Note: On Vertical tanks - 0° = North On Horizontal tanks - 0° = Top V-110 M 15-10-M		NORTH 0°/360°	NORTH EAST 45°	EAST 90°	SOUTH EAST 135°	SOUTH 180°	SOUTH WEST 225°	WEST 270°	NOR WES 315°
	TOP	$\boxed{258}$		267		$\boxed{258}$		276	
	UPPER	271		271		$\boxed{267}$		270	
	MIDDLE								
	LOWER	263		$\boxed{260}$		270		290	
	BOTTOM	272		$\boxed{268}$		286		290	
	CONE								

Respectfully submitted,
PROFESSIONAL SERVICE INDUSTRIES, INC.
C. Hubbuch

5555 Canal Road • Cleveland, OH 44125 • Phone: 216/447-1335 • Fax: 216/642-7008

Professional Service Industries, Inc.

TESTED FOR:	Hukill Chemical Corporation 7013 Krick Road Bedford, Ohio 44146	PROJECT:	Tank Wall Thickness Measurements
DATE:	June 1994	OUR REPORT NO.:	138-48041-001



Note: On Vertical tanks - 0° = North On Horizontal tanks - 0° = Top V-210-M 14-10-M		NORTH 0°/360°	NORTH EAST 45°	EAST 90°	SOUTH EAST 135°	SOUTH 180°	SOUTH WEST 225°	WEST 270°	NORTH WEST 315°
	TOP	245 240		251 249		261 250		257 242	
	UPPER								
	MIDDLE								
	LOWER								
	BOTTOM	264		255		265		259	
	CONE	310 313		323 311		318 296		322 325	

Respectfully submitted,
PROFESSIONAL SERVICE INDUSTRIES, INC.
C. Hubbuch

Structural Assessment of a Hazardous Waste Storage Tank
for Hukill Chemical Company

4 x 3M Feed Tank System - Tanks 8-3-F thru 11-3-F
Exhibit D-7

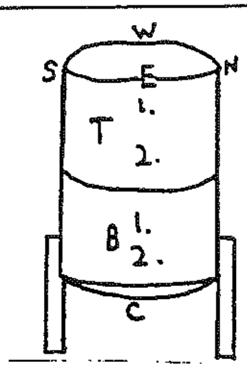
Summary of Minimum Tank Wall Measurements
Professional Service Industries, Inc.
Report No. 138-48041-004 - Dated September 22, 1995

	8-3-F	9-3-F	10-3-F	11-3-F
PSI Report Sheet	[3.14]	[3.12]	[3.12]	[3.13]
Top 1	165	167	157	$\boxed{151}$
Top 2	$\boxed{154}$	165	157	160
Bottom 1	$\boxed{151}$	168	158	156
Bottom 2	157	167	162	$\boxed{151}$
Cone	227	225	238	$\boxed{224}$

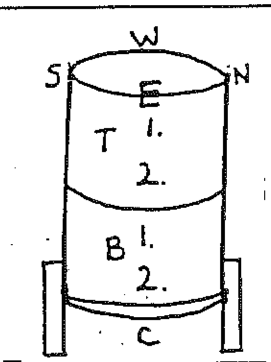
$\boxed{}$ = Critical Wall Thickness

psi *Environmental Geotechnical Construction*
Consulting • Engineering • Testing

TESTED FOR:	Hukill Chemical Corporation 7013 Krick Road Bedford, Ohio 44146	PROJECT:	Tank Wall Thickness Measurements
DATE:	September 22, 1995	OUR REPORT NO.:	138-48041-004



Note: On Vertical tanks - 0° = North On Horizontal tanks - 0° = Top 10-3-F		NORTH 0°/360°	NORTH EAST 45°	EAST 90°	SOUTH EAST 135°	SOUTH 180°	SOUTH WEST 225°	WEST 270°	NORTH WEST 315°
	TOP	160 159		158 168		158 162		157 157	
	UPPER								
	MIDDLE								
	LOWER								
	BOTTOM	158 162		170 170		160 166		161 165	
	CONE	238		240		239		239	

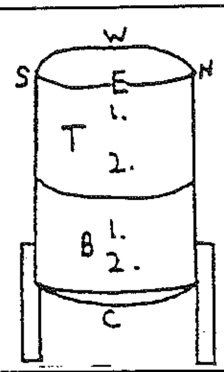


Note: On Vertical tanks - 0° = North On Horizontal tanks - 0° = Top 9-3-F		NORTH 0°/360°	NORTH EAST 45°	EAST 90°	SOUTH EAST 135°	SOUTH 180°	SOUTH WEST 225°	WEST 270°	NORTH WEST 315°
	TOP	168 165		169 166		167 170		172 169	
	UPPER								
	MIDDLE								
	LOWER								
	BOTTOM	169 169		170 168		168 170		170 167	
	CONE	232		225		232		230	

Respectfully submitted,
PROFESSIONAL SERVICE INDUSTRIES, INC.
L. Mach

psi Environmental Geotechnical Construction
Consulting • Engineering • Testing

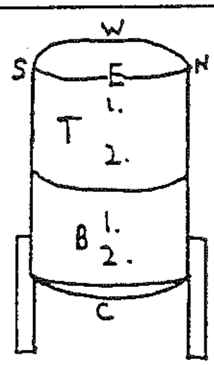
TESTED FOR:	Hukill Chemical Corporation 7013 Krick Road Bedford, Ohio 44146	PROJECT:	Tank Wall Thickness Measurements
DATE:	September 22, 1995	OUR REPORT NO.:	138-48041-004

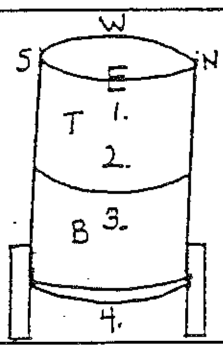
Note: On Vertical tanks - 0° = North On Horizontal tanks - 0° = Top 11-3-F		NORTH 0°/360°	NORTH EAST 45°	EAST 90°	SOUTH EAST 135°	SOUTH 180°	SOUTH WEST 225°	WEST 270°	NORTH WEST 315°
	TOP	159 160		151 160		154 160		156 165	
	UPPER								
	MIDDLE								
	LOWER								
	BOTTOM	156 151		159 156		164 157		172 166	
	CONE	226		225		227		224	

Respectfully submitted,
PROFESSIONAL SERVICE INDUSTRIES, INC.
L. Mach

psi Environmental Geotechnical Construction
Consulting • Engineering • Testing

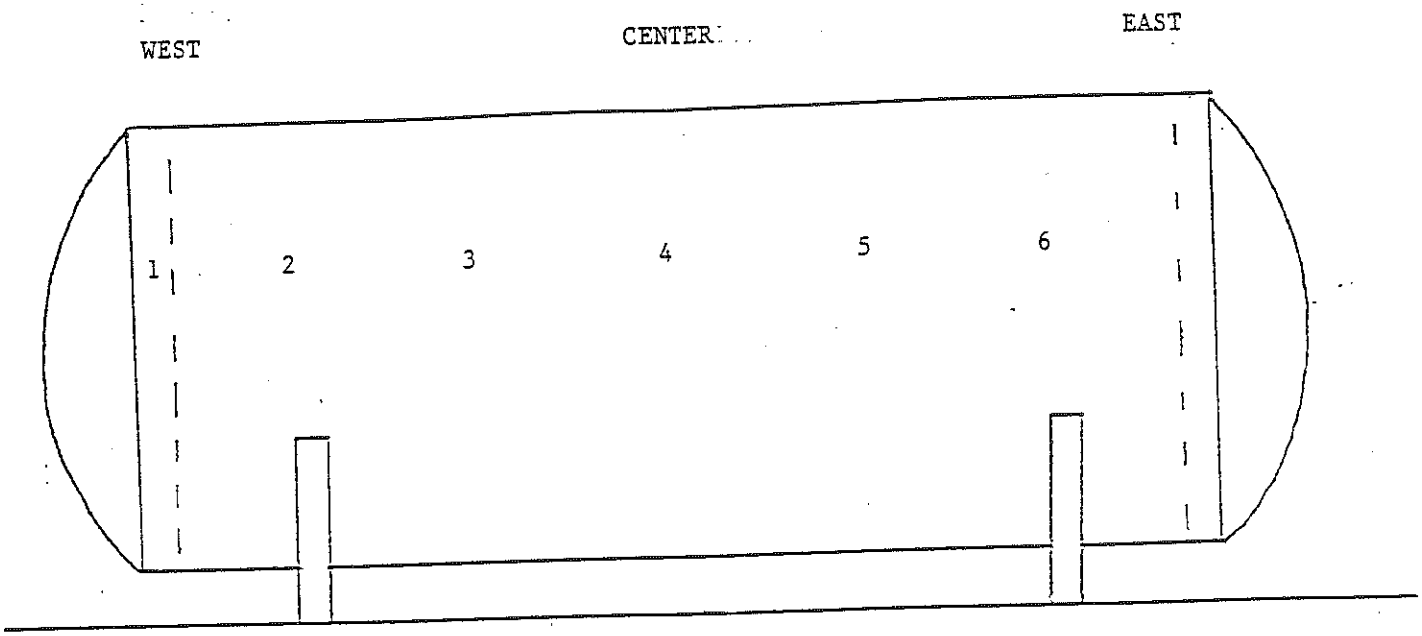
TESTED FOR:	Hukill Chemical Corporation 7013 Krick Road Bedford, Ohio 44146	PROJECT:	Tank Wall Thickness Measurements
DATE:	September 22, 1995	OUR REPORT NO.:	138-48041-004

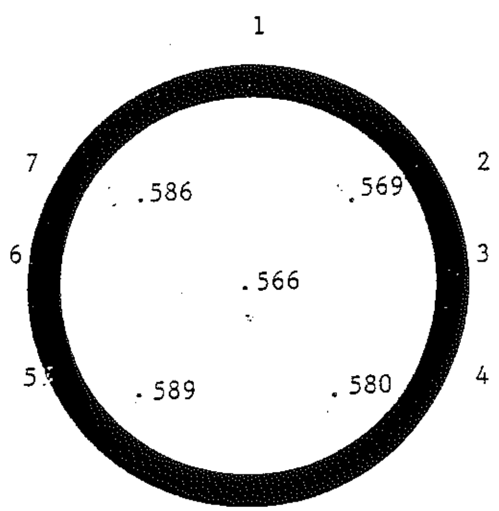
Note: On Vertical tanks - 0° = North On Horizontal tanks - 0° = Top 8-3-F		NORTH 0°/360°	NORTH EAST 45°	EAST 90°	SOUTH EAST 135°	SOUTH 180°	SOUTH WEST 225°	WEST 270°	NORTH WEST 315°
	TOP	169 154		165 155		168 167		173 155	
	UPPER								
	MIDDLE								
	LOWER								
	BOTTOM	157 161		165 157		156 161		151 165	
	CONE	227		231		237		249	

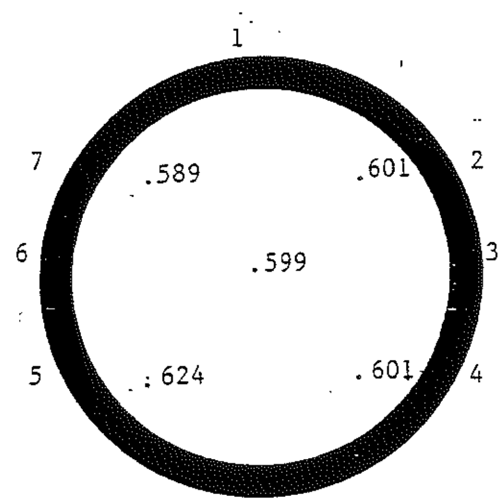
Hockmeyer Mixer		NORTH 0°/360°	NORTH EAST 45°	EAST 90°	SOUTH EAST 135°	SOUTH 180°	SOUTH WEST 225°	WEST 270°	NORTH WEST 315°
	TOP	248 244		249 247		249 n/a		248 251	
	UPPER								
	MIDDLE								
	LOWER								
	BOTTOM	243		250		258		243	
	CONE			254				257	

Respectfully submitted,
PROFESSIONAL SERVICE INDUSTRIES, INC.
L. Mach

SPENT TANK #1786







	1	2	3	4	5	6
1.	.601	.594	.598	.599	.608	.612
2.	.607	.608	.612	.613	.616	.608
3.	.568	.552	.559	.539	.529	.547
4.	.581	.593	.553	.563	.575	.584
5.	.591	.598	.594	.576	.580	.586
6.	.576	.578	.576	.568	.571	.582
7.	.547	.533	.534	.525	.526	.535

$$A_T = h\left[\tfrac{1}{2}(y_0 + y_n) + y_1 + y_2 + \ldots + y_{n-1}\right]$$
(Trapezoidal Rule)

$$A_D = h\left[0.4\,(y_0 + y_n) + 1.1\,(y_1 + y_{n-1}) + y_2 + y_3 + \ldots + y_{n-2}\right]$$
(Durand's Rule)

$$A_S = \tfrac{1}{3}h\left[(y_0 + y_n) + 4\,(y_1 + y_3 + \ldots + y_{n-1}) + 2\,(y_2 + y_4 + \ldots + y_{n-2})\right]$$
(Simpson's Rule, where n is even).

The larger the value of n, the greater is the accuracy of approximation. In general, for the same number of chords, A_S gives the most accurate, A_T, the least accurate approximation.

51 Cube

$V = a^3$; $d = a\sqrt{3}$.
Total surface $= 6\,a^2$.

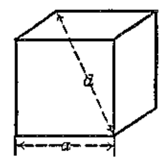


FIG. 51.

52 Rectangular Parallelopiped

$V = abc$; $d = \sqrt{a^2 + b^2 + c^2}$.
Total surface $= 2\,(ab + bc + ca)$.

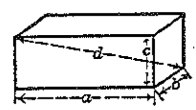


FIG. 52.

53 Prism or Cylinder

$V =$ (area of base) $\times$ (altitude).
Lateral area $=$ (perimeter of right section) $\times$ (lateral edge).

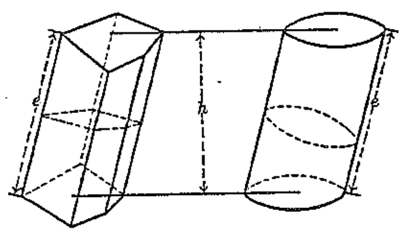


FIG. 53.

54 Pyramid or Cone

$V = \frac{1}{3}$ (area of base) $\times$ (altitude).
Lateral area of regular figure $= \frac{1}{2}$ (perimeter of base) $\times$ (slant height).

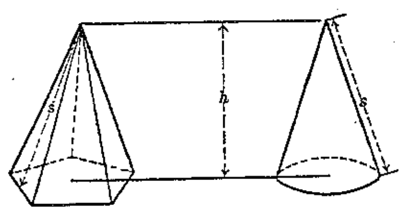


FIG. 54.

55 Frustum of Pyramid or Cone

$V = \frac{1}{3}(A_1 + A_2 + \sqrt{A_1 \times A_2})\,h$, where A_1 and A_2 are areas of bases, and h is altitude.
Lateral area of regular figure $= \frac{1}{2}$ (sum of perimeters of bases) $\times$ (slant height).

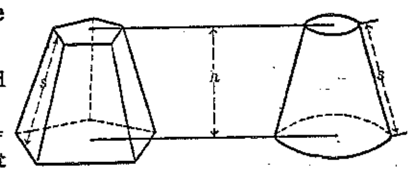


FIG. 55.

43 Trapezium (no sides parallel)

$A = \frac{1}{2}(ah_1 + bh_2)$ = sum of areas of 2 triangles.

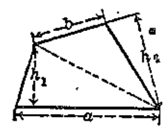


FIG. 43.

44 Regular Polygon of n Sides $\left\{\begin{array}{l}\text{all sides equal}\\ \text{all angles equal}\end{array}\right\}$

$$\beta = \frac{n-2}{n}\,180^\circ = \frac{n-2}{n}\,\pi \text{ radians.}$$

$$\alpha = \frac{360^\circ}{n} = \frac{2\pi}{n} \text{ radians.}$$

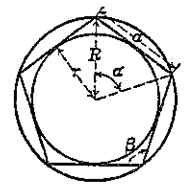


FIG. 44.

n	a	r	R	A
3	$2r\sqrt{3} = R\sqrt{3}$	$\frac{1}{6}a\sqrt{3}$	$\frac{1}{3}a\sqrt{3}$	$\frac{1}{4}a^2\sqrt{3} = 3r^2\sqrt{3} = \frac{3}{4}R^2\sqrt{3}$
4	$2r = R\sqrt{2}$	$\frac{1}{2}a$	$\frac{1}{2}a\sqrt{2}$	$a^2 = 4r^2 = 2R^2$
6	$\frac{2}{3}r\sqrt{3} = R$	$\frac{1}{2}a\sqrt{3}$	a	$\frac{3}{2}a^2\sqrt{3} = 2r^2\sqrt{3} = \frac{3}{2}R^2\sqrt{3}$
8	$2r(\sqrt{2}-1) = R\sqrt{2-\sqrt{2}}$	$\frac{1}{2}a(\sqrt{2}+1)$	$\frac{1}{2}a\sqrt{4+2\sqrt{2}}$	$2a^2(\sqrt{2}+1) = 8r^2(\sqrt{2}-1) = 2R^2\sqrt{2}$
n	$2r\tan\frac{\alpha}{2} = 2R\sin\frac{\alpha}{2}$	$\frac{a}{2}\cot\frac{\alpha}{2}$	$\frac{a}{2}\csc\frac{\alpha}{2}$	$\frac{na^2}{4}\cot\frac{\alpha}{2} = nr^2\tan\frac{\alpha}{2} = \frac{nR^2}{2}\sin\alpha$

45 Circle $\left\{\begin{array}{l}C = \text{circumference}\\ \alpha = \text{central angle in radians}\end{array}\right\}$

$C = \pi D = 2\pi R.$

$$c = R\alpha = \tfrac{1}{2}D\alpha = D\cos^{-1}\frac{d}{R} = D\tan^{-1}\frac{l}{2d}.$$

$$l = 2\sqrt{R^2-d^2} = 2R\sin\frac{\alpha}{2} = 2d\tan\frac{\alpha}{2} = 2d\tan\frac{c}{D}.$$

$$d = \tfrac{1}{2}\sqrt{4R^2-l^2} = \tfrac{1}{2}\sqrt{D^2-l^2} = R\cos\frac{\alpha}{2} = \tfrac{1}{2}l\cot\frac{\alpha}{2} = \tfrac{1}{2}l\cot\frac{c}{D}.$$

$h = R - d.$

$$\alpha = \frac{c}{R} = \frac{2c}{D} = 2\cos^{-1}\frac{d}{R} = 2\tan^{-1}\frac{l}{2d} = 2\sin^{-1}\frac{l}{D}.$$

$A_{(\text{circle})} = \pi R^2 = \frac{1}{4}\pi D^2 = \frac{1}{2}RC = \frac{1}{4}DC.$

$A_{(\text{sector})} = \frac{1}{2}Rc = \frac{1}{2}R^2\alpha = \frac{1}{8}D^2\alpha.$

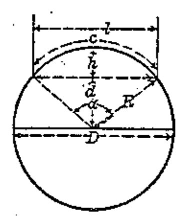


FIG. 45.

[5]

32 Properties of Plane Triangles

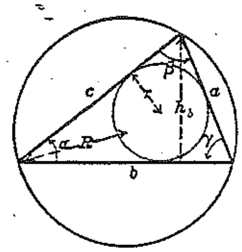


FIG. 32.

Notation. α, β, γ = angles; a, b, c = sides.
A = area; h_b = altitude on b; $s = \frac{1}{2}(a + b + c)$.
r = radius of inscribed circle; R = radius of circumscribed circle.

$$\alpha + \beta + \gamma = 180° = \pi \text{ radians}$$

$$\frac{a}{\sin \alpha} = \frac{b}{\sin \beta} = \frac{c}{\sin \gamma}.$$

$$\frac{a + b}{a - b} = \frac{\tan \frac{1}{2}(\alpha + \beta)}{\tan \frac{1}{2}(\alpha - \beta)}.^*$$

$$a^2 = b^2 + c^2 - 2\,bc \cos \alpha,^* \quad a = b \cos \gamma + c \cos \beta.^*$$

$$\cos \alpha = \frac{b^2 + c^2 - a^2}{2\,bc},^* \quad \sin \alpha = \frac{2}{bc}\sqrt{s(s-a)(s-b)(s-c)}.^*$$

$$\sin \frac{\alpha}{2} = \sqrt{\frac{(s-b)(s-c)}{bc}},^* \quad \cos \frac{\alpha}{2} = \sqrt{\frac{s(s-a)}{bc}},^*$$

$$\tan \frac{\alpha}{2} = \sqrt{\frac{(s-b)(s-c)}{s(s-a)}} = \frac{r}{s-a}.^*$$

$$h_b = c \sin \alpha\,^* = a \sin \gamma\,^* = \frac{2}{b}\sqrt{s(s-a)(s-b)(s-c)}.^*$$

$$r = \sqrt{\frac{(s-a)(s-b)(s-c)}{s}} = (s-a)\tan \frac{\alpha}{2}.^*$$

$$R = \frac{a}{2 \sin \alpha}^* = \frac{abc}{4\,A}.$$

$$A = \tfrac{1}{2}\,bh_b{}^* = \tfrac{1}{2}\,ab \sin \gamma\,^* = \frac{a^2 \sin \beta \sin \gamma}{2 \sin \alpha}^* = \sqrt{s(s-a)(s-b)(s-c)} = rs.$$

33 Solution of the Right Triangle

Given any two sides, or one side and any acute angle, α, to find the remaining parts.

$$\sin \alpha = \frac{a}{c}, \quad \cos \alpha = \frac{b}{c}, \quad \tan \alpha = \frac{a}{b}, \; \beta = 90° - \alpha.$$

$$a = \sqrt{(c+b)(c-b)} = c \sin \alpha = b \tan \alpha.$$

$$b = \sqrt{(c+a)(c-a)} = c \cos \alpha = \frac{a}{\tan \alpha}.$$

$$c = \frac{a}{\sin \alpha} = \frac{b}{\cos \alpha} = \sqrt{a^2 + b^2}.$$

$$A = \tfrac{1}{2}\,ab = \frac{a^2}{2 \tan \alpha} = \frac{b^2 \tan \alpha}{2} = \frac{c^2 \sin 2\alpha}{4}.$$

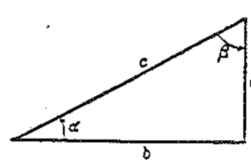


FIG. 33.

* Two more formulas may be obtained by replacing a by b, b by c, c by a, α by β, β by γ, γ by α.

[6]

$$A_T = h\left[\tfrac{1}{2}(y_0 + y_n) + y_1 + y_2 + \dots + y_{n-1}\right]$$
(Trapezoidal Rule)

$$A_D = h\left[0.4(y_0 + y_n) + 1.1(y_1 + y_{n-1}) + y_2 + y_3 + \dots + y_{n-2}\right]$$
(Durand's Rule)

$$A_S = \tfrac{1}{3}h\left[(y_0 + y_n) + 4(y_1 + y_3 + \dots + y_{n-1}) + 2(y_2 + y_4 + \dots + y_{n-2})\right]$$
(Simpson's Rule, where n is even).

The larger the value of n, the greater is the accuracy of approximation. In general, for the same number of chords, A_S gives the most accurate, A_T, the least accurate approximation.

51 Cube

$V = a^3$; $d = a\sqrt{3}$.
Total surface $= 6\,a^2$.

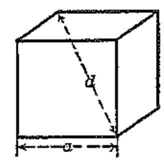


FIG. 51.

52 Rectangular Parallelopiped

$V = abc$; $d = \sqrt{a^2 + b^2 + c^2}$.
Total surface $= 2\,(ab + bc + ca)$.

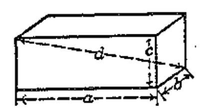


FIG. 52.

53 Prism or Cylinder

V = (area of base) × (altitude).
Lateral area = (perimeter of right section) × (lateral edge).

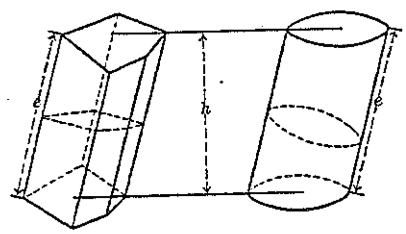


FIG. 53.

54 Pyramid or Cone

$V = \frac{1}{3}$ (area of base) × (altitude).
Lateral area of regular figure = $\frac{1}{2}$ (perimeter of base) × (slant height).

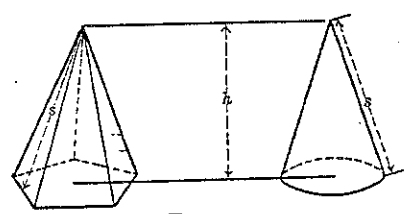


FIG. 54.

55 Frustum of Pyramid or Cone

$V = \frac{1}{3}(A_1 + A_2 + \sqrt{A_1 \times A_2})\,h$, where A_1 and A_2 are areas of bases, and h is altitude.
Lateral area of regular figure = $\frac{1}{2}$ (sum of perimeters of bases) × (slant height).

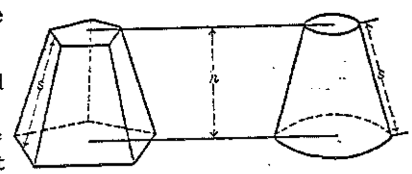


FIG. 55.

[7]

WEIGHT OF RECTANGULAR SECTIONS
Pounds per linear foot

Width In.	Thickness, Inches 3/16	1/4	5/16	3/8	7/16	1/2	9/16	5/8	11/16	3/4	13/16	7/8	15/16	1
1/4	0.16	0.21	0.27	0.32	0.37	0.43	0.48	0.53	0.58	0.64	0.69	0.74	0.80	0.85
1/2	0.32	0.43	0.53	0.64	0.74	0.85	0.96	1.06	1.17	1.28	1.38	1.49	1.60	1.70
3/4	0.48	0.64	0.80	0.96	1.12	1.28	1.44	1.60	1.75	1.91	2.07	2.23	2.39	2.55
1	0.64	0.85	1.06	1.28	1.49	1.70	1.91	2.13	2.34	2.55	2.76	2.98	3.19	3.40
1 1/4	0.80	1.06	1.33	1.60	1.86	2.13	2.39	2.66	2.92	3.19	3.46	3.72	3.99	4.25
1 1/2	0.96	1.28	1.60	1.91	2.23	2.56	2.87	3.19	3.51	3.83	4.15	4.47	4.79	5.10
1 3/4	1.12	1.49	1.86	2.23	2.61	2.98	3.35	3.72	4.09	4.47	4.84	5.21	5.58	5.95
2	1.28	1.70	2.13	2.55	2.98	3.40	3.83	4.25	4.68	5.10	5.53	5.95	6.38	6.81
2 1/4	1.44	1.91	2.39	2.87	3.35	3.83	4.31	4.79	5.26	5.74	6.22	6.70	7.18	7.66
2 1/2	1.60	2.13	2.66	3.19	3.72	4.25	4.79	5.32	5.85	6.38	6.91	7.44	7.96	8.51
2 3/4	1.75	2.34	2.92	3.51	4.09	4.68	5.26	5.85	6.43	7.02	7.60	8.19	8.77	9.36
3	1.91	2.55	3.19	3.83	4.47	5.10	5.74	6.38	7.02	7.66	8.29	8.93	9.57	10.2
3 1/4	2.07	2.76	3.46	4.15	4.84	5.53	6.22	6.91	7.60	8.29	8.99	9.68	10.4	11.1
3 1/2	2.23	2.98	3.72	4.47	5.21	5.95	6.70	7.44	8.19	8.93	9.68	10.4	11.2	11.9
3 3/4	2.39	3.19	3.99	4.79	5.58	6.38	7.18	7.98	8.77	9.57	10.4	11.2	12.0	12.8
4	2.55	3.40	4.25	5.10	5.95	6.81	7.66	8.51	9.36	10.2	11.1	11.9	12.8	13.6
4 1/4	2.71	3.62	4.52	5.42	6.33	7.23	8.13	9.04	9.94	10.8	11.8	12.7	13.6	14.5
4 1/2	2.87	3.83	4.79	5.74	6.70	7.66	8.61	9.57	10.5	11.5	12.4	13.4	14.4	15.3
4 3/4	3.03	4.04	5.05	6.06	7.07	8.08	9.09	10.1	11.1	12.1	13.1	14.1	15.2	16.2
5	3.19	4.25	5.32	6.38	7.44	8.51	9.57	10.6	11.7	12.8	13.8	14.9	16.0	17.0
5 1/4	3.35	4.47	5.58	6.70	7.82	8.93	10.0	11.2	12.3	13.4	14.5	15.6	16.7	17.9
5 1/2	3.51	4.68	5.85	7.02	8.19	9.36	10.5	11.7	12.9	14.0	15.2	16.4	17.5	18.7
5 3/4	3.67	4.89	6.11	7.34	8.56	9.78	11.0	12.2	13.5	14.7	15.9	17.1	18.3	19.6
6	3.83	5.10	6.38	7.66	8.93	10.2	11.5	12.8	14.0	15.3	16.6	17.9	19.1	20.4
6 1/4	3.99	5.32	6.65	7.98	9.30	10.6	12.0	13.3	14.6	16.0	17.3	18.6	19.9	21.3
6 1/2	4.15	5.53	6.91	8.29	9.68	11.1	12.4	13.8	15.2	16.6	18.0	19.4	20.7	22.1
6 3/4	4.31	5.74	7.18	8.61	10.0	11.5	12.9	14.4	15.8	17.2	18.7	20.1	21.5	23.0
7	4.47	5.95	7.44	8.93	10.4	11.9	13.4	14.9	16.4	17.9	19.4	20.8	22.3	23.8
7 1/4	4.63	6.17	7.71	9.25	10.8	12.3	13.9	15.4	17.0	18.5	20.0	21.6	23.1	24.7
7 1/2	4.79	6.38	7.98	9.57	11.2	12.8	14.4	16.0	17.5	19.1	20.7	22.3	23.9	25.5
7 3/4	4.94	6.59	8.24	9.89	11.5	13.2	14.8	16.5	18.1	19.8	21.4	23.1	24.7	26.4
8	5.10	6.81	8.51	10.2	11.9	13.6	15.3	17.0	18.7	20.4	22.1	23.8	25.5	27.2
8 1/2	5.42	7.23	9.04	10.8	12.7	14.5	16.3	18.1	19.9	21.7	23.5	25.3	27.1	28.9
9	5.74	7.66	9.57	11.5	13.4	15.3	17.2	19.1	21.1	23.0	24.9	26.8	28.7	30.6
9 1/2	6.06	8.08	10.1	12.1	14.1	16.2	18.2	20.2	22.2	24.2	26.3	28.3	30.3	32.3
10	6.38	8.51	10.6	12.8	14.9	17.0	19.1	21.3	23.4	25.5	27.6	29.8	31.9	34.0
10 1/2	6.70	8.93	11.2	13.4	15.6	17.9	20.1	22.3	24.6	26.8	29.0	31.3	33.5	35.7
11	7.02	9.36	11.7	14.0	16.4	18.7	21.1	23.4	25.7	28.1	30.4	32.8	35.1	37.4
11 1/2	7.34	9.78	12.2	14.7	17.1	19.6	22.0	24.5	26.9	29.3	31.8	34.2	36.7	39.1
12	7.66	10.2	12.8	15.3	17.9	20.4	23.0	25.5	28.1	30.6	33.2	35.7	38.3	40.8

8-1

STAINLESS SHEETS

304, 304L and Nitronic™ 30

Cold Rolled, Annealed and Pickled.

Finishes: 2B, #3 and #4

304: ASTM A240, ASME SA240, QQS 766, MIL-S 5059, and AMS 5513

304L: ASTM A240, ASME SA240, QQS 766, and AMS 5511

Nitronic 30: ASTM A240, A666

Sizes in Stock

Gauge & Size in Inches	Thickness in Inches	Est. Wt. per Sq. Ft. in Lbs.	Est. Wt. per Sheet in Lbs.	304	304L	Nitronic 30
7 . . . 36 x 120	.1874	7.871	236.1	X	..	..
48 x 120	.1874	7.871	314.8	X	X	..
48 x 144	.1874	7.871	377.8	X	X	..
60 x 120	.1874	7.871	393.6	X	X	..
60 x 144	.1874	7.871	472.3	X	X	..
8 . . . 36 x 120	.1650	6.930	207.9	X	..	..
48 x 120	.1650	6.930	277.2	X	X	..
48 x 144	.1650	6.930	332.6	X	..	..
60 x 120	.1650	6.930	346.5	X	..	..
60 x 144	.1650	6.930	415.8	X	..	..
72 x 120	.1650	6.930	415.8	X	..	..
10 . . . 36 x 96	.1350	5.670	136.1	X	..	..
36 x 120	.1350	5.670	170.1	X	..	..
36 x 144	.1350	5.670	204.1	X	..	..
42 x 120	.1350	5.670	198.5	X	..	..
48 x 96	.1350	5.670	181.4	X	..	..
48 x 120	.1350	5.670	226.8	X	X	X
48 x 144	.1350	5.670	272.2	X	X	..
48 x 240	.1350	5.670	453.6	X	..	..
60 x 96	.1350	5.670	226.8	X	..	..
60 x 120	.1350	5.670	283.5	X	X	..
60 x 144	.1350	5.670	340.2	X	..	..
60 x 240	.1350	5.670	567.0	X	..	..
72 x 120	.1350	5.670	340.2	X	..	..
72 x 144	.1350	5.670	408.2	X	..	..
11 . . . 36 x 96	.1200	5.040	121.0	X	..	..
36 x 120	.1200	5.040	151.2	X	..	..
36 x 144	.1200	5.040	181.4	X	..	..
42 x 120	.1200	5.040	176.4	X	..	..
48 x 96	.1200	5.040	161.3	X	..	..
48 x 120	.1200	5.040	201.6	X	X	X
48 x 144	.1200	5.040	241.9	X	..	..
60 x 96	.1200	5.040	201.6	X	..	..
60 x 120	.1200	5.040	252.0	X	X	..
60 x 144	.1200	5.040	302.4	X	..	..
72 x 120	.1200	5.040	302.4	X	..	..
72 x 144	.1200	5.040	362.9	X	..	..

3/16"

(Continued)

[1] Also stocked as BA.

8.2

BOLTS, THREADED PARTS AND RIVETS
Shear
Allowable load in kips

TABLE I-D. SHEAR

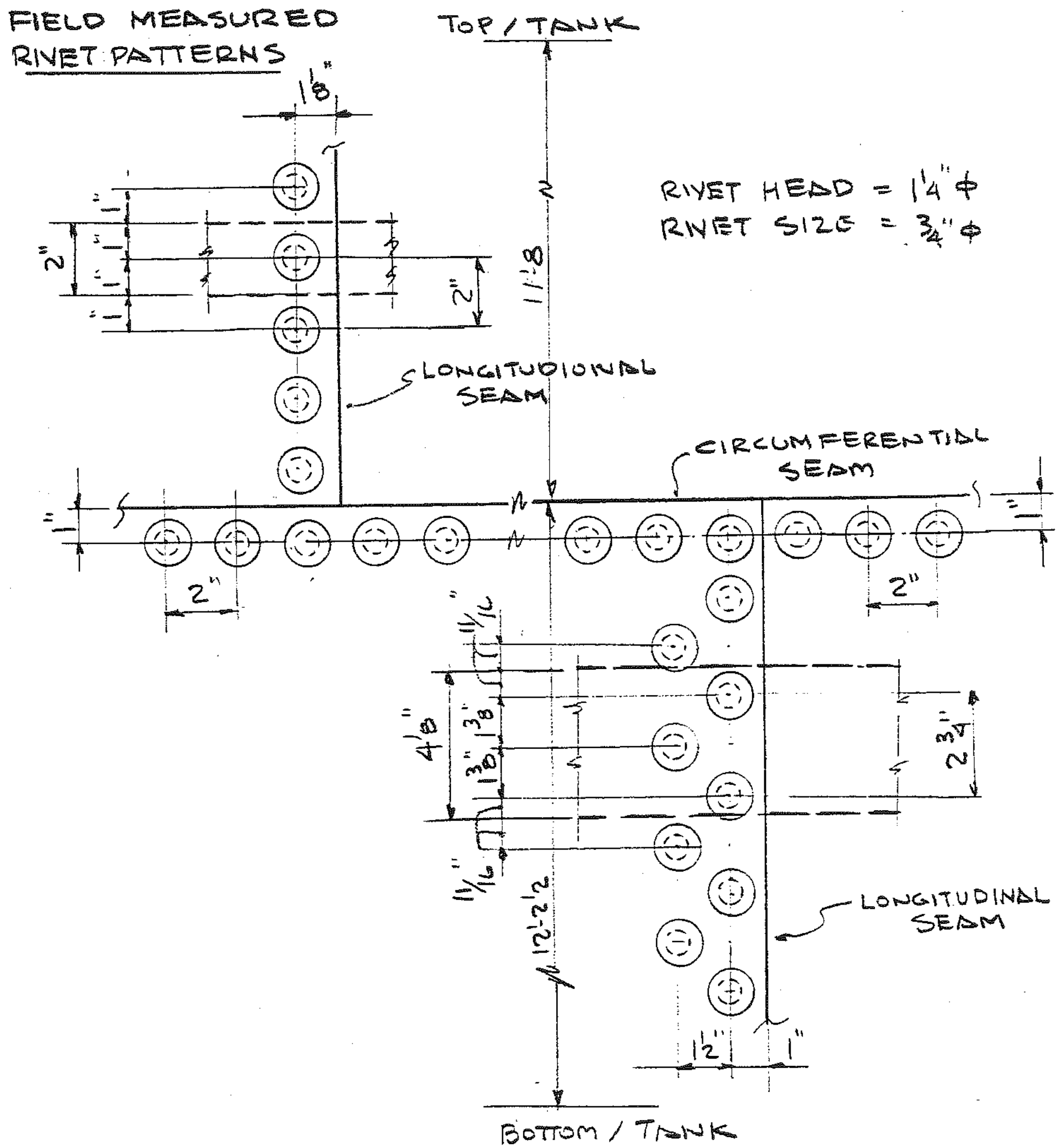
	ASTM Designation	Connection Type[a]	Hole Type[b]	F_u ksi	Loading[c]	Nominal Diameter d, in.							
						5/8	3/4	7/8	1	1 1/8	1 1/4	1 3/8	1 1/2
						Area (Based on Nominal Diameter) in.^{2}							
						.3068	.4418	.6013	.7854	.9940	1.227	1.485	1.767
Bolts	A307	—	STD NSL	10.0	S	3.1	4.4	6.0	7.9	9.9	12.3	14.8	17.7
					D	6.1	8.8	12.0	15.7	19.9	24.5	29.7	35.3
	A325	SC[a] Class A	STD	17.0	S	5.22	7.51	10.2	13.4	16.9	20.9	25.2	30.0
					D	10.4	15.0	20.4	26.7	33.8	41.7	50.5	60.1
			OVS, SSL	15.0	S	4.60	6.63	9.02	11.8	14.9	18.4	22.3	26.5
					D	9.20	13.3	18.0	23.6	29.8	36.8	44.6	53.0
			LSL	12.0	S	3.68	5.30	7.22	9.42	11.9	14.7	17.8	21.2
					D	7.36	10.6	14.4	18.8	23.9	29.4	35.6	42.4
		N	STD, NSL	21.0	S	6.4	9.3	12.6	16.5	20.9	25.8	31.2	37.1
					D	12.9	18.6	25.3	33.0	41.7	51.5	62.4	74.2
		X	STD, NSL	30.0	S	9.2	13.3	18.0	23.6	29.8	36.8	44.5	53.0
					D	18.4	26.5	36.1	47.1	59.6	73.6	89.1	106.0
	A490	SC[a] Class A	STD	21.0	S	6.44	9.28	12.6	16.5	20.9	25.8	31.2	37.1
					D	12.9	18.6	25.3	33.0	41.7	51.5	62.4	74.2
			OVS, SSL	18.0	S	5.52	7.95	10.8	14.1	17.9	22.1	26.7	31.8
					D	11.0	15.9	21.6	28.3	35.8	44.2	53.5	63.6
			LSL	15.0	S	4.60	6.63	9.02	11.8	14.9	18.4	22.3	26.5
					D	9.20	13.3	18.0	23.6	29.8	36.8	44.6	53.0
		N	STD, NSL	28.0	S	8.6	12.4	16.8	22.0	27.8	34.4	41.6	49.5
					D	17.2	24.7	33.7	44.0	55.7	68.7	83.2	99.0
		X	STD, NSL	40.0	S	12.3	17.7	24.1	31.4	39.8	49.1	59.4	70.7
					D	24.5	35.3	48.1	62.8	79.5	98.2	119.0	141.0
Rivets	A502-1	—	STD	$\boxed{17.5}$	S	5.4	$\boxed{7.7}$	10.5	13.7	17.4	21.5	26.0	30.9
					D	10.7	15.5	21.0	27.5	34.8	42.9	52.0	61.8
	A502-2 A502-3	—	STD	22.0	S	6.7	9.7	13.2	17.3	21.9	27.0	32.7	38.9
					D	13.5	19.4	26.5	34.6	43.7	54.0	65.3	77.7
Threaded Parts	A36 (F_u=58 ksi)	N	STD	9.9	S	3.0	4.4	6.0	7.8	9.8	12.1	14.7	17.5
					D	6.1	8.7	11.9	15.6	19.7	24.3	29.4	35.0
		X	STD	12.8	S	3.9	5.7	7.7	10.1	12.7	15.7	19.0	22.6
					D	7.9	11.3	15.4	20.1	25.4	31.4	38.0	45.2
	A572, Gr. 50 (F_u=65 ksi)	N	STD	11.1	S	3.4	4.9	6.7	8.7	11.0	13.6	16.5	19.6
					D	6.8	9.8	13.3	17.4	22.1	27.2	33.0	39.2
		X	STD	14.3	S	4.4	6.3	8.6	11.2	14.2	17.5	21.2	25.3
					D	8.8	12.6	17.2	22.5	28.4	35.1	42.5	50.5
	A588 (F_u=70 ksi)	N	STD	11.9	S	3.7	5.3	7.2	9.3	11.8	14.6	17.7	21.0
					D	7.3	10.5	14.3	18.7	23.7	29.2	35.3	42.1
		X	STD	15.4	S	4.7	6.8	9.3	12.1	15.3	18.9	22.9	27.2
					D	9.4	13.6	18.5	24.2	30.6	37.8	45.7	54.4

[a]SC = Slip critical connection.
N: Bearing-type connection with threads *included* in shear plane.
X: Bearing-type connection with threads *excluded* from shear plane.
[b]STD: Standard round holes (d + 1/16 in.)
OVS: Oversize round holes
LSL: Long-slotted holes
SSL: Short-slotted holes
NSL: Long-or short-slotted hole normal to load direction (required in bearing-type connection).
[c]S: Single shear D: Double shear.
For threaded parts of materials not listed, use $F_v = 0.17F_u$ when threads are included in a shear plane, and $F_v = 0.22F_u$ when threads are excluded from a shear plane.
To fully pretension bolts 1⅛-in. dia. and greater, special impact wrenches may be required.
When bearing-type connections used to splice tension members have a fastener pattern whose length, measured parallel to the line of force, exceeds 50 in., tabulated values shall be reduced by 20%. See AISC ASD Commentary Sect. J3.4.

[9]

Structural Assessment of a Hazardous Waste Storage Tank
for Hukill Chemical Company

7 Tank Dike System - Tanks V-114 thru V-614



Since tanks must be tested with water, a specific gravity g less than 1 is not recommended for design purposes.

2. Shell Design. The shell plate is made up of one or more horizontal plate courses of width w (usually about 8 ft). Several plates may be required to make up each course. The vertical seams are staggered relative to the vertical seams in adjacent plate courses. Tank shells are cylindrical membranes designed to resist hoop tension (Fig. 1). Plate thickness is calculated at the bottom edge of each course.

$$T_h = 2.60hDg \tag{3}$$

$$t_h = \frac{T_h}{fE} = \frac{2.60hDg}{fE} \tag{4}$$

where T_h = shell tension, lb per in., at depth h
h = depth from top of tank, ft
E = joint efficiency factor
f = allowable unit stress, psi
t_h = shell plate thickness, in.

For welded construction, E varies from 0.35 to 1.0 depending on the type of joint used and the required welding-inspection procedure. Lap-welded joints, where used, are based on fillet welds the full thickness of the plates joined. Lap welds in tank bottoms and roof plates not in contact with water are single-lap-welded from the top side only. Lap welds in roofs and shell plates in contact with water are double-lap-welded.

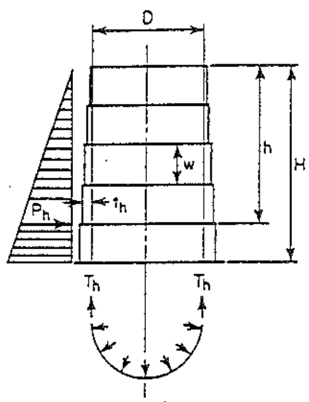


FIG. 1

The joint efficiencies specified in Table 1 are based on nominal inspection of the welding. The owner may specify full magnafluxing in addition to nominal inspection. Only full-penetration butt-welded joints are permitted at joint efficiencies greater than 0.75, and the joint efficiency may exceed 0.85 only when rigid inspection (extended radiographic examination) is provided. Partial-penetration butt welds are permissible only in tank shell joints subjected to secondary stress, such as horizontal seams, for which the direct vertical stress is usually negligible. However, when heavy vertical loads are supported by the shell, the vertical stress is considered to be a principal stress and the horizontal seams require full-penetration butt welding.

Table 1. Efficiencies of Welded Joints

Type of welded joint	E	Remarks
Single lap	0.35	Continuous welds
Double lap	0.75	Continuous welds
Partial-penetration butt (⅔ min)	0.66	Tension joints
Partial-penetration butt (⅔ min)	1.00	Compression joints
Full-penetration butt	0.85	Tension joints
Full-penetration butt	1.00	Compression joints

3. Bottom Plates. The flat bottoms in reservoirs are usually grade-supported, the liquid load on the top side being resisted by an equal upward foundation soil pressure. Steel bottoms usually have a minimum thickness of ¼ in. The plates are lap-welded to each other top side only for liquid tightness (Fig. 2). Figure 3 shows the simple detail required for connecting the bottom to the tank shell.

Support of relatively light shells requires no special consideration. When the of the biaxial stresses can be determined by statics. The upward hydrostatic pressure on a horizontal plane at the distance h below the high-water line will be balanced by a system of meridional membrane stresses T_2 (Fig. 18). Thus

$$T_2 = \frac{\gamma h \pi D'^2/4 - W_w}{\pi D' \cos \theta} \tag{24}$$

where D' = diameter of membrane at cut section
γ = density of product stored
The weight of the metal should be included in the determination of T_2.

To determine the other (latitudinal) membrane stress T_1, equilibrium of T_1 and T_2 with the hydrostatic pressure p normal to the surface at the depth h gives

$$T_1 = R_1 \left(p - \frac{T_2}{R_2} \right) \tag{25}$$

where R_1 = latitudinal radius
R_2 = meridional radius
Several points should be checked to determine maximum compressive stress. The computed maximum stress will determine the required roof-plate thickness. The curvature in the meridional direction determines the compressive buckling strength in the latitudinal direction, whereas the latitudinal curvature determines the compressive buckling strength in the meridional direction.

Having computed T_1 and T_2 the next step is to determine the required plate thickness. Allowable tensile unit stresses are governed by the tensile properties of the material. Allowable compressive unit stresses are governed by buckling strength, which can be determined by the Boardman formula for mild steels,

$$f_a = 2{,}000{,}000 \frac{t}{R} \left(1 - \frac{100}{3} \frac{t}{R} \right) \tag{26}$$

where t = plate thickness, in.
R = curvature normal to direction of stress, in.
f_a = allowable compression stress, psi* (limited to 15,000 psi in current AWWA Specifications)

10. Suspended Bottoms. Design of suspended bottoms formed by a surface of revolution is similar to that of the roof. The bottom is sectioned by a transverse plane, the stresses T_1 and T_2 determined, and the required plate thickness calculated. In hemispherical bottoms, where $R_1 = R_2 = R$, the maximum tensile stress, which occurs at the very bottom (Fig. 17), is

$$T_1 = T_2 = \frac{\gamma H R}{2} \tag{27}$$

The stresses at the spring line are

$$T_1 = \gamma R \left(\frac{h'}{2} - \frac{R}{3} \right) \tag{28}$$

$$T_2 = \gamma R \left(\frac{h'}{2} + \frac{R}{3} \right) \tag{29}$$

where R = spherical radius of bottom
H = distance from high-water line to bottom of tank
h' = distance from high-water line to spring line of bottom
The stresses T_1 and T_2 in suspended conical bottoms are determined independently

* Factor of safety = 2.

[11]-2

(Fig. 19). When the cylindrical portion is filled to a depth X above the cone-to-cylinder junction, the stresses in the cone at any point h_c below the spring line are

$$T_2 = \frac{\gamma}{2\cos\theta}\left(\frac{D}{2} - h_c \tan\theta\right)\left(X + \frac{2h_c}{3} + \frac{D}{6}\cot\theta\right) \tag{30}$$

$$T_1 = \frac{\gamma}{\cos\theta}\left(\frac{D}{2} - h_c \tan\theta\right)(X + h_c) \tag{31}$$

At the spring line the stresses are

$$T_2 = \frac{\gamma}{2\cos\theta}\frac{D}{2}\left(X + \frac{D}{6}\cot\theta\right) \tag{32}$$

$$T_1 = \frac{\gamma D X}{2\cos\theta} \tag{33}$$

where θ = apex angle
At the apex $T_2 = T_1 = 0$.

Compression stresses must also be determined at the cone-to-cylinder junction, where a compression girder is required to resist the inward pull of the cone bottom (Fig. 31a). The compression force C in the girder is

$$C = \frac{\gamma}{8}\left(X + \frac{D}{6}\cot\theta\right) D^2 \tan\theta \tag{34}$$

Portions of cone and shell act with the girder. The effective width of each strip is assumed to be $0.78\sqrt{Rt}$ but not to exceed $16t$. Therefore, the effective area is the smaller of

$$A_{\text{eff}} = 0.78(t_c\sqrt{R_c t_c} + t_1\sqrt{R_1 t_1}) \tag{35a}$$

$$A_{\text{eff(max)}} = 16(t_c^2 + t_1^2) \tag{35b}$$

where R_c, R_1 = radius of shell, cone
t_c, t_1 = thickness of shell, cone

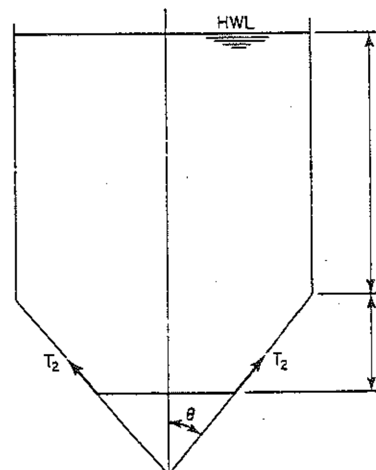


FIG. 19. Membrane forces in suspended bottom.

11. Balcony or Ring Girder. The shell of a column-supported tank is considered to be a circular girder uniformly loaded over its periphery and supported by columns, equally spaced on the shell circumference, attached directly to the tank shell. The supporting tower generates concentrated radial and tangential forces on the tank structure. These forces may be caused by sloping columns and/or the diagonal bracing system in the tower, and a ring girder must be provided to resist them. The ring girder is located at the intersection of the column's neutral axis with the tank shell and is usually positioned at the spring line of the suspended bottom. It also functions as the top strut line of the tower. A tank balcony can serve as a ring girder. Balconies should be wide enough to permit walking upright around the tank and should provide easy passage at the columns. If a balcony is not used, some form of ring girder must be provided.

The force system on the balcony or ring girder of a tank having vertical columns consists of the shears q in the shell resulting from the horizontal load H at strut line or balcony due to wind or seismic forces, and the resisting forces in the bracing

[11]-3

CHAPTER B

DESIGN REQUIREMENTS

This chapter contains provisions which are common to the Specification as a whole.

B1. GROSS AREA

The gross area of a member at any point shall be determined by summing the products of the thickness and the gross width of each element as measured normal to the axis of the member.

For angles, the gross width shall be the sum of the widths of the legs less the thickness.

B2. NET AREA

The net area A_n of a member is the sum of the products of the thickness and the net width of each element computed as follows:

The width of a bolt or rivet hole shall be taken as 1/16 in. greater than the nominal dimension of the hole.

For a chain of holes extending across a part in any diagonal or zigzag line, the net width of the part shall be obtained by deducting from the gross width the sum of the diameters or slot dimensions as provided in Sect. J3.2, of all holes in the chain, and adding, for each gage space in the chain, the quantity

$$s^2/4g$$

where

s = longitudinal center-to-center spacing (pitch) of any two consecutive holes, in.

g = transverse center-to-center spacing (gage) between fastener gage lines, in.

For angles, the gage for holes in opposite adjacent legs shall be the sum of the gages from the back of the angles less the thickness.

The critical net area A_n of the part is obtained from that chain which gives the least net width.

In determining the net area across plug or slot welds, the weld metal shall not be considered as adding to the net area.

B3. EFFECTIVE NET AREA

When the load is transmitted directly to each of the cross-sectional elements by connectors, the effective net area A_e is equal to the net area A_n.

where,

L_e = distance from the free edge to center of the bolt, in.
d = bolt dia., in.

If deformation around the hole is not a design consideration and adequate spacing and edge distance is as required by Sects. J3.8 and J3.9, the following equation is permitted in lieu of Equation (J3-1):

$$F_p = 1.5\ F_u \tag{J3-4}$$

and the limit in Equation (J3-3) shall be increased to $1.5F_u$.

8. Minimum Spacing

The distance between centers of standard, oversized or slotted fastener holes shall not be less than 2⅔ times the nominal diameter of the fastener* nor less than that required by the following paragraph, if applicable.

Along a line of transmitted forces, the distance between centers of holes s shall be not less than $3d$ when F_p is determined by Equations (J3-1) and (J3-2). Otherwise, the distance between centers of holes shall not be less than the following:

a. For standard holes:

$$s \leq 2P/F_u t + d/2 \tag{J3-5}$$

where

P = force transmitted by one fastener to the critical connected part, kips
F_u = specified minimum tensile strength of the critical connected part, ksi
t = thickness of the critical connected part, in.

b. For oversized and slotted holes, the distance required for standard holes in subparagraph a, (above), plus the applicable increment C_1 from Table J3.4, but the clear distance between holes shall not be less than one bolt diameter.

9. Minimum Edge Distance

The distance from the center of a standard hole to an edge of a connected part shall be not less than the applicable value from Table J3.5 nor the value from Equation (J3-6), as applicable.

Along a line of transmitted force, in the direction of the force, the distance from the center of a standard hole to the edge of the connected part L_e shall be not less than $1\frac{1}{2}d$ when F_p is determined by Equations (J3-1) or (J3-2). Otherwise the edge distance shall be not less than

$$L_e \leq 2P/F_u t \tag{J3-6}$$

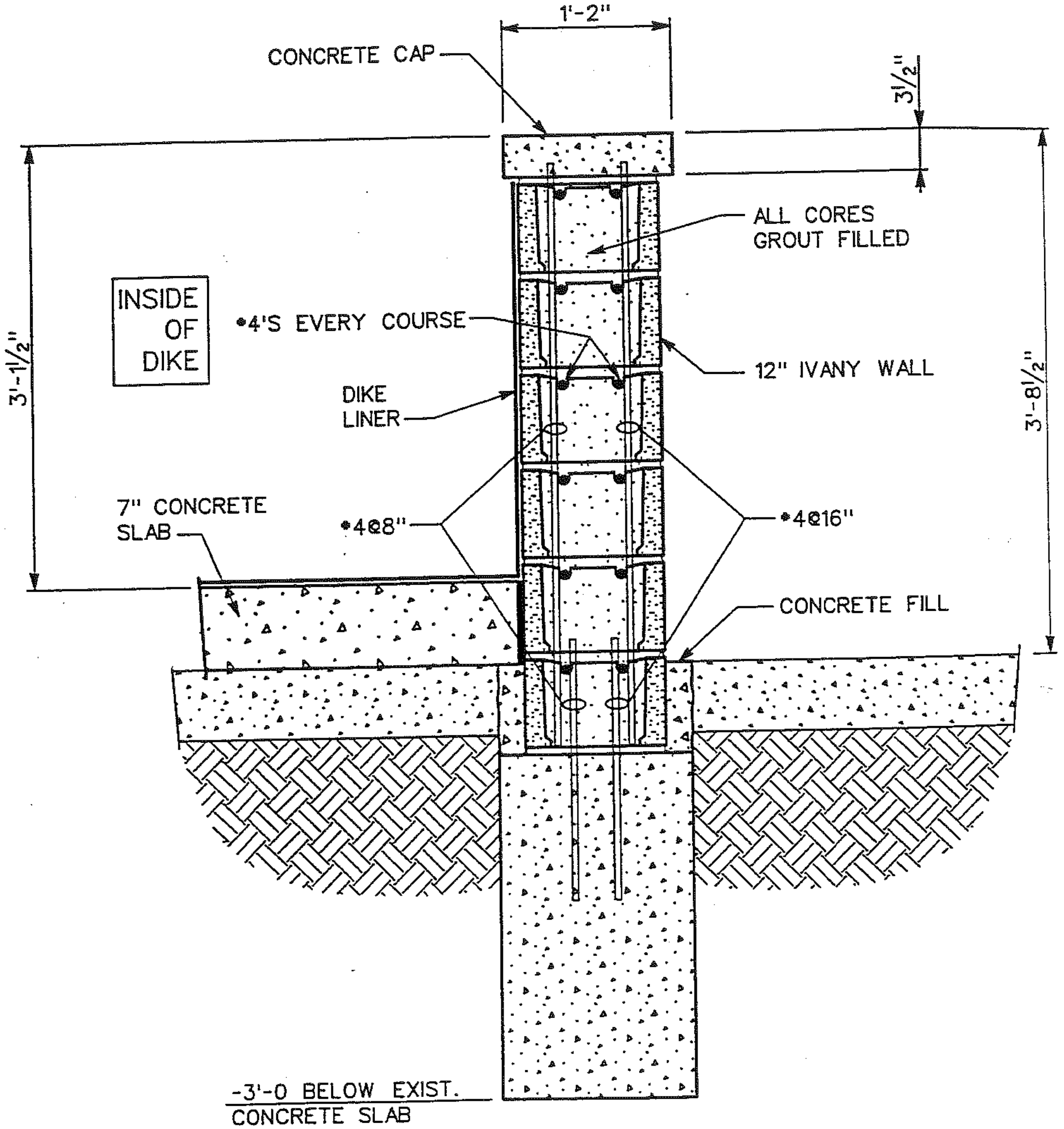
where P, F_u, t are defined in Sect. J3.8.

*A distance of $3d$ is preferred.

Structural Assessment of a Hazardous Waste Storage Tank for Hukill Chemical Company

Index of
Index of Dike Wall Drawings and Sketches

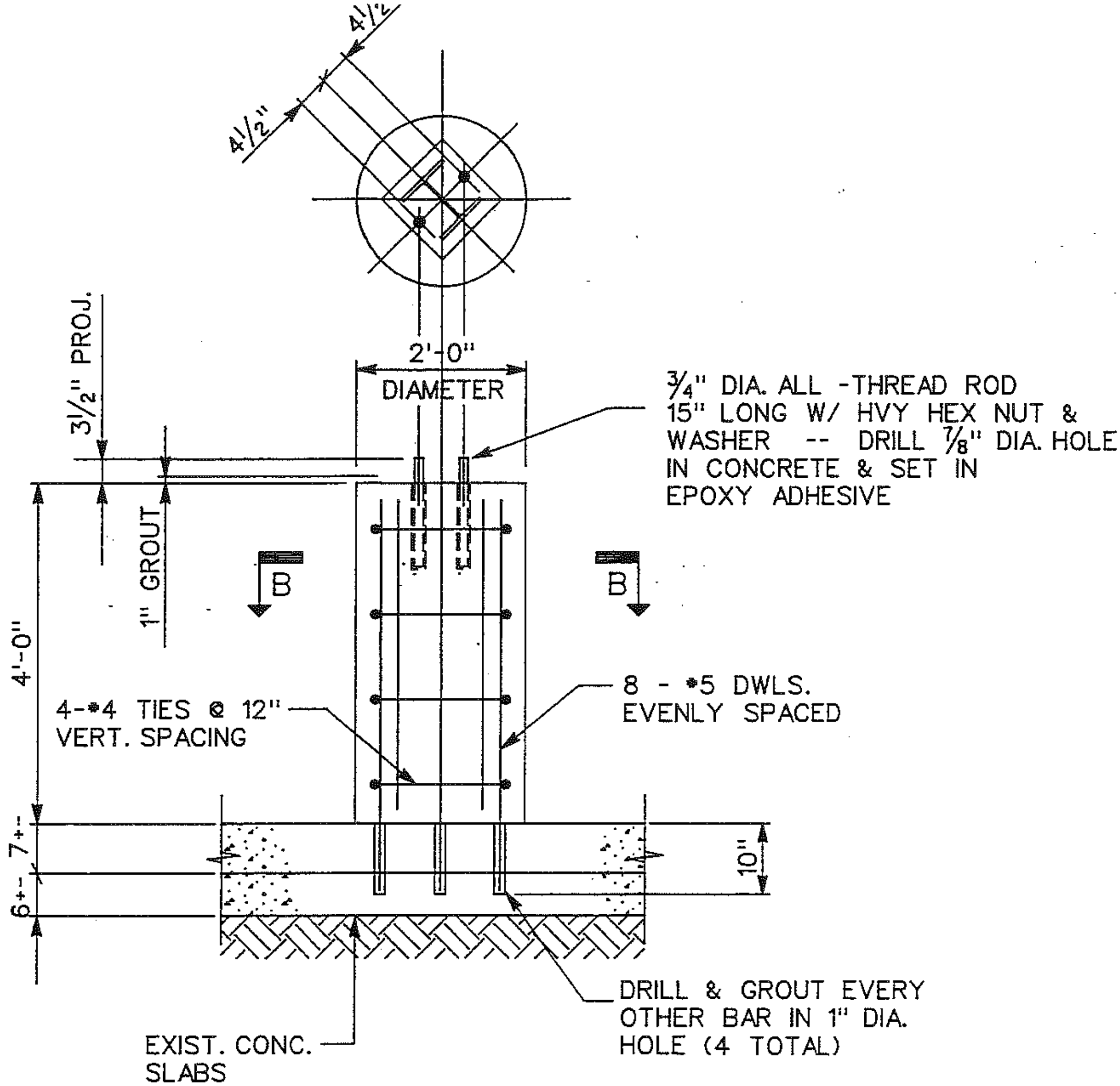
Dike I.D.	Exhibit	Ref.	Drawing Description
7 Tank Dike	D-2	[14.1]	H.C.C. Reduced Drawing 1294-F1, Plan Sheet 10
BTMS/Feed	D-10	[14.2]	H.C.C. Reduced Drawing 1700-F1, Plan Sheet 11C
F-1 Fuels Dike	D-6	[14.3a] [14.3b] [14.3c]	Sketch of Ivany Block Wall Sketch of Tank Pier Sketch of Existing Tank Layout
4X3M Feed Tanks	D-7		No Drawing - Described in Tank Calculations
Disperser Tank	D-8		No Dike Wall
Spent Acid Tank	D-9		No Drawing - Described in Tank Calculations



TYPICAL WALL

1"=1'-0

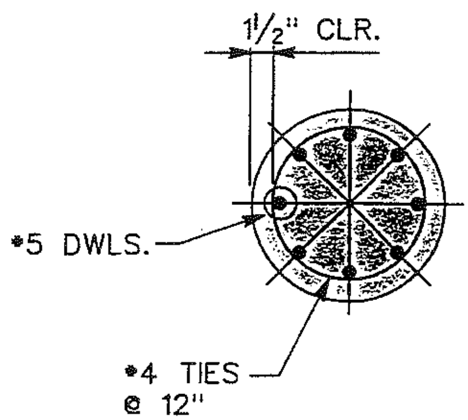
[14.3a]



NEW PIER DETAIL

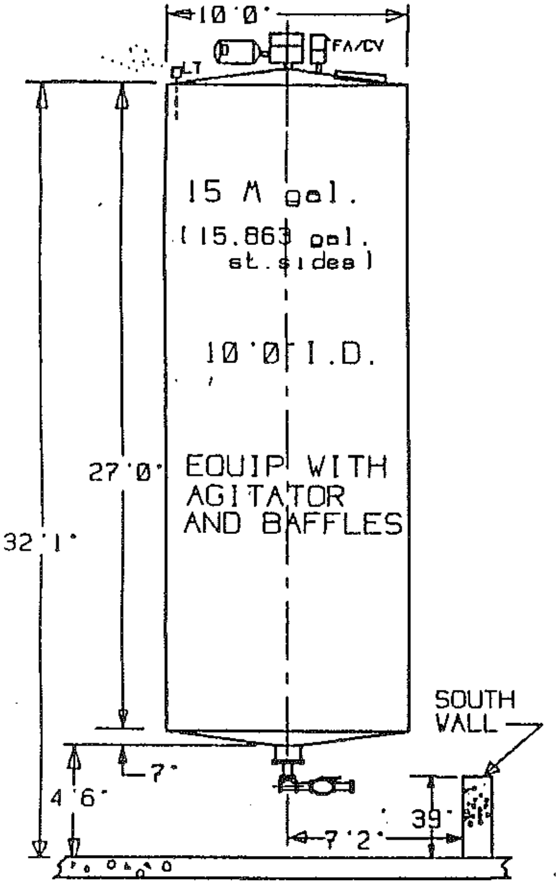
4 REQUIRED

½" = 1'-0

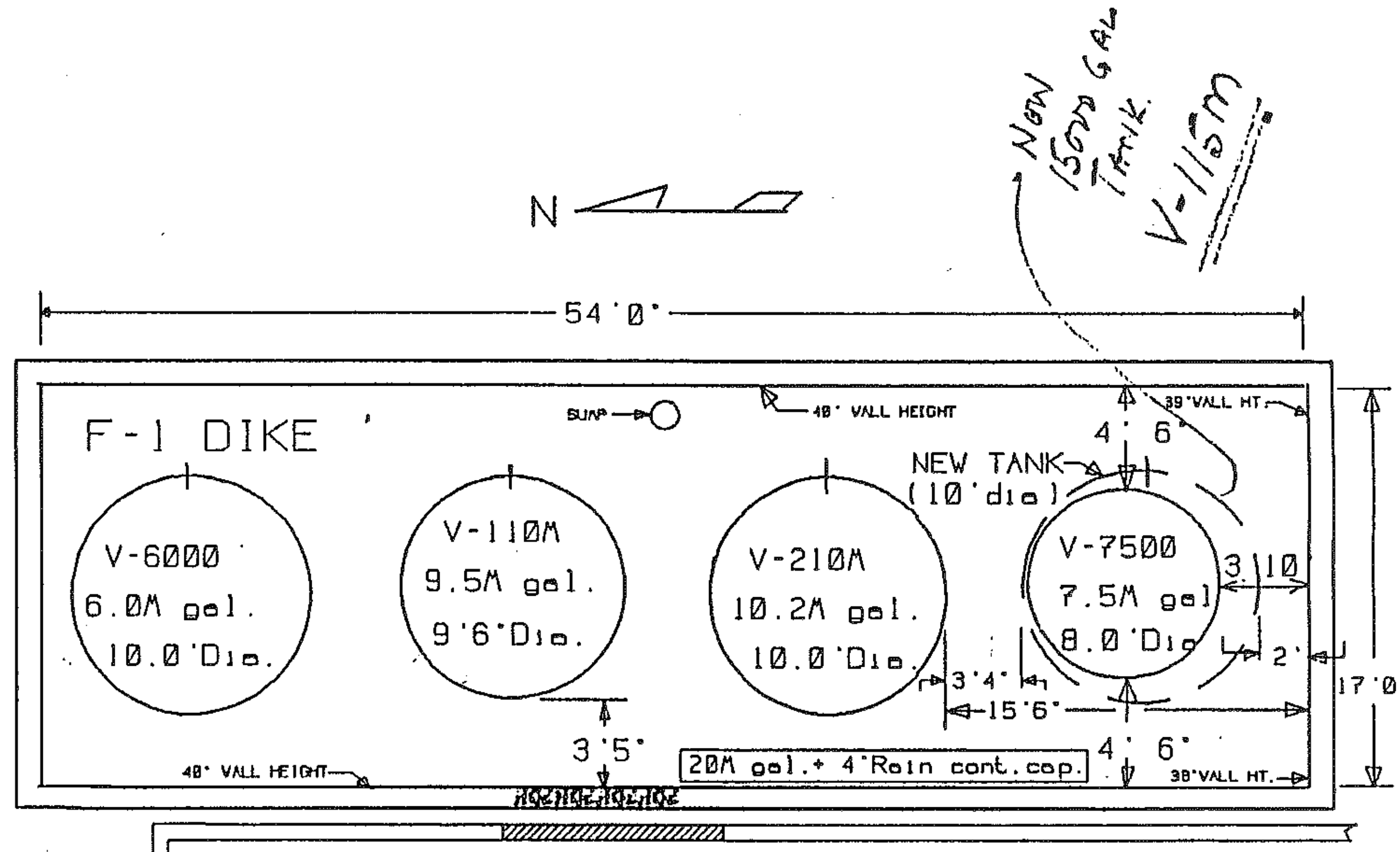


SECTION B-B

½" = 1'-0



PROPOSED REPLACEMENT TANK



EXISTING TANK LAYOUT

◁— H.W. FUELS PROCESSING AREA —▷

TANK INFORMATION

TANK	HEIGHT	DIAMETER	S/S HT.
V-6000	16.75'	10.0'	8.75'
V-110M	24.0'	9.5'	19.0'
V-210M	26'6"	10.0'	15'0"
V-750M	REPLACE	8.0'	DISH
NEW TK.	32'8"	10.0'	27'0"

HUKILL CHEMICAL CORPORATION

\HWFUELS\HWFUELSA.DWG Rev. 1/29/92

Scale: 1/8" = 1'

Table 3a. Areas and Perimeters of Bars in Sections 1 Ft. Wide (Slabs)

Areas A_s (or A'_s) (top) sq. in.; Perimeters Σo, (bottom) in.

Enter table with values of A_s (or A'_s) and $\Sigma o = \frac{V}{7/8\,du}$ (V: lb; d: in.; u: psi)

Coefficients $a = \frac{f_s}{12,000} \times j$ inserted in table are for use in $A_s = \frac{M}{ad}$ or $A_s = \frac{NE}{adi}$

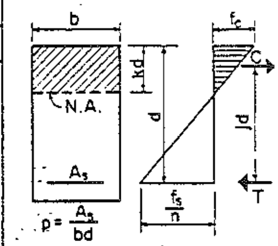
Spacing	#2	#3	#4	#5	#6	#7	#8	#9	#10	#11	Spacing
2	0.30 4.7	0.66 7.1	1.20 9.4	1.86 11.8	2.64 14.2						2
2-1/2	0.24 3.8	0.53 5.7	0.96 7.5	1.49 9.4	2.11 11.3	2.88 13.2	3.79 15.1				2-1/2
3	0.20 3.1	0.44 4.7	0.80 6.3	1.24 7.8	1.76 9.4	2.40 11.0	3.16 12.6	4.00 14.2			3
3-1/2	0.17 2.7	0.38 4.0	0.69 5.4	1.06 6.7	1.51 8.1	2.06 9.4	2.71 10.8	3.43 12.2	4.36 13.7		3-1/2
4	0.15 2.4	0.33 3.5	0.60 4.7	0.93 5.9	1.32 7.1	1.80 8.3	2.37 9.4	3.00 10.6	3.81 12.0	4.68 13.3	4
4-1/2	0.13 2.1	0.29 3.1	0.53 4.2	0.83 5.2	1.17 6.3	1.60 7.3	2.11 8.4	2.67 9.5	3.39 10.6	4.16 11.8	4-1/2
5	0.12 1.9	0.26 2.8	0.48 3.8	0.74 4.7	1.06 5.7	1.44 6.6	1.90 7.5	2.40 8.5	3.05 9.6	3.74 10.6	5
5-1/2	0.11 1.7	0.24 2.6	0.44 3.4	0.68 4.3	0.96 5.1	1.31 6.0	1.72 6.9	2.18 7.7	2.77 8.7	3.40 9.7	5-1/2
6	0.10 1.6	0.22 2.4	0.40 3.1	0.62 3.9	0.88 4.7	1.20 5.5	1.58 6.3	2.00 7.1	2.54 8.0	3.12 8.9	6
6-1/2	0.09 1.4	0.20 2.2	0.37 2.9	0.57 3.6	0.81 4.4	1.11 5.1	1.46 5.8	1.85 6.5	2.35 7.4	2.88 8.2	6-1/2
7	0.09 1.3	0.19 2.0	0.34 2.7	0.53 3.4	0.75 4.0	1.03 4.7	1.35 5.4	1.71 6.1	2.18 6.8	2.67 7.6	7
7-1/2	0.08 1.3	0.18 1.9	0.32 2.5	0.50 3.1	0.70 3.8	0.96 4.4	1.26 5.0	1.60 5.7	2.03 6.4	2.50 7.1	7-1/2
8	0.08 1.2	0.17 1.8	0.30 2.4	0.47 2.9	0.66 3.5	0.90 4.1	1.19 4.7	1.50 5.3	1.91 6.0	2.34 6.6	8
8-1/2	0.07 1.1	0.16 1.7	0.28 2.2	0.44 2.8	0.62 3.3	0.85 3.9	1.12 4.4	1.41 5.0	1.79 5.6	2.20 6.2	8-1/2
9	0.07 1.0	0.15 1.6	0.27 2.1	0.41 2.6	0.59 3.1	0.80 3.7	1.05 4.2	1.33 4.7	1.69 5.3	2.08 5.9	9
9-1/2	0.06 1.0	0.14 1.5	0.25 2.0	0.39 2.5	0.56 3.0	0.76 3.5	1.00 4.0	1.26 4.5	1.60 5.0	1.97 5.6	9-1/2
10	0.06 0.9	0.13 1.4	0.24 1.9	0.37 2.4	0.53 2.8	0.72 3.3	0.95 3.8	1.20 4.3	1.52 4.8	1.87 5.3	10
10-1/2	0.06 0.9	0.13 1.3	0.23 1.8	0.35 2.2	0.50 2.7	0.69 3.1	0.90 3.6	1.14 4.0	1.45 4.6	1.78 5.1	10-1/2
11	0.05 0.9	0.12 1.3	0.22 1.7	0.34 2.2	0.48 2.6	0.65 3.0	0.86 3.4	1.09 3.9	1.39 4.4	1.70 4.8	11
11-1/2	0.05 0.08	0.11 1.2	0.21 1.6	0.32 2.0	0.46 2.5	0.63 2.9	0.82 3.3	1.04 3.7	1.33 4.2	1.63 4.6	11-1/2
12	0.05 0.8	0.11 1.2	0.20 1.6	0.31 2.0	0.44 2.4	0.60 2.8	0.79 3.1	1.00 3.5	1.27 4.0	1.56 4.4	12
13	f_s	a	0.18 1.4	0.29 1.8	0.41 2.2	0.55 2.5	0.73 2.9	0.92 3.3	1.17 3.7	1.44 4.1	13
14	16,000 18,000	1.13 1.29	0.17 1.3	0.27 1.7	0.38 2.0	0.51 2.4	0.68 2.7	0.86 3.0	1.09 3.4	1.34 3.8	14
15	20,000 22,000	1.44 1.60	0.16 1.3	0.25 1.6	0.35 1.9	0.48 2.2	0.63 2.5	0.80 2.8	1.02 3.2	1.25 3.5	15
16	24,000 27,000	1.76 2.00	0.15 1.2	0.23 1.5	0.33 1.8	0.45 2.1	0.59 2.4	0.75 2.7	0.95 3.0	1.17 3.3	16
17	30,000 33,000	2.24 2.48	0.14 1.1	0.22 1.4	0.31 1.7	0.42 1.9	0.56 2.2	0.71 2.5	0.90 2.8	1.10 3.1	17
18			$\boxed{0.13}$ 1.0	0.21 1.3	0.29 1.6	0.40 1.8	0.53 2.1	0.67 2.4	0.85 2.7	1.04 3.0	18

Table 3b. Properties of Steel Reinforcing Bars

	Nominal dimensions— round sections											
	Bar designation No.											
	2	3	4	5	6	7	8	9	10	11	14S	18S
Unit Weight per ft., lb.	0.167	0.376	0.668	1.043	1.502	2.044	2.670	3.400	4.303	5.313	7.65	13.60
Diameter in.	0.250	0.375	0.500	0.625	0.750	0.875	1.000	1.128	1.270	1.410	1.693	2.257
Cross-sectional area, sq. in.	0.05	0.11	0.20	0.31	0.44	0.60	0.79	1.00	1.27	1.56	2.25	4.00
Perimeter, in.	0.786	1.178	1.571	1.963	2.356	2.749	3.142	3.544	3.990	4.430	5.32	7.09

Table 1. Coefficients *(K, k, j, p)* for Rectangular Sections

f'_c and n	f_c	K	k	j	p	K	k	j	p
		f_s = 16,000		a = 1.13		f_s = 18,000		a = 1.29	
2500	875.	137.	.356	.881	.0097	128.	.329	.890	.0080
	1000.	169.	.387	.871	.0121	158.	.359	.880	.0100
	1125.	201.	.415	.862	.0146	190.	.387	.871	.0121
10.1	1250.	235.	.441	.853	.0172	222.	.412	.863	.0143
	1500.	306.	.486	.838	.0228	291.	.457	.848	.0190
3000	1050.	173.	.376	.875	.0124	162.	.349	.884	.0102
	1200.	212.	.408	.864	.0153	199.	.380	.873	.0127
	1350.	252.	.437	.854	.0184	238.	.408	.864	.0153
9.2	1500.	294.	.463	.846	.0217	278.	.434	.855	.0181
	1800.	380.	.509	.830	.0286	362.	.479	.840	.0240
4000	1400.	249.	.412	.863	.0180	234.	.384	.872	.0149
	1600.	303.	.444	.852	.0222	286.	.416	.861	.0185
	1800.	359.	.474	.842	.0266	341.	.444	.852	.0222
8.0	2000.	417.	.500	.833	.0313	397.	.471	.843	.0261
	2400.	536.	.545	.818	.0409	513.	.516	.828	.0344
5000	1750.	327.	.437	.854	.0239	309.	.408	.864	.0199
	2000.	397.	.470	.843	.0294	376.	.441	.853	.0245
	2250.	468.	.500	.833	.0351	446.	.470	.843	.0294
7.1	2500.	542.	.526	.825	.0411	518.	.497	.835	.0345
	3000.	694.	.571	.810	.0535	666.	.542	.819	.0452



$p = \frac{A_s}{bd}$

$k = \frac{1}{1 + f_s/nf_c}$ $\quad j = 1 - \frac{1}{3}k$

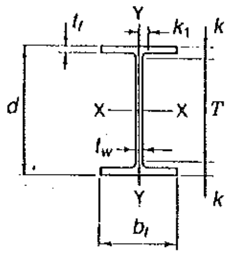
$p^* = \frac{f_c}{2f_s} \times k$ $\quad K = \frac{f_c}{2}kj$

$a = \frac{f_s}{12,000} \times$ (aver. j-value)

for use in $A_s = \frac{M}{ad}$ or $A_s = \frac{NE}{adi}$

f'_c and n	f_c	K	k	j	p	K	k	j	p	K	k	j	p
		f_s = 20,000		a = 1.44		f_s = 22,000		a = 1.60		f_s = 24,000		$\boxed{a = 1.76}$	
2500	875.	120.	.306	.898	.0067	113.	.287	.904	.0057	107.	.269	.910	.0049
	1000.	149.	.336	.888	.0084	141.	.315	.895	.0072	133.	.296	.901	.0062
	1125.	179.	.362	.879	.0102	170.	.341	.886	.0087	161.	.321	.893	.0075
10.1	1250.	211.	.387	.871	.0121	200.	.365	.878	.0104	191.	.345	.885	.0090
	1500.	277.	.431	.856	.0162	264.	.408	.864	.0139	253.	.387	.871	.0121
3000	1050.	152.	.326	.891	.0085	144.	.305	.898	.0073	136.	.287	.904	.0063
	1200.	188.	.356	.881	.0107	178.	.334	.889	.0091	169.	.315	.895	.0079
	$\boxed{1350.}$	226.	.383	.872	.0129	214.	.361	.880	.0111	204.	.341	.886	.0096
9.2	1500.	265.	.408	.864	.0153	252.	.385	.872	.0131	240.	.365	.878	.0114
	1800.	346.	.453	.849	.0204	331.	.429	.857	.0176	317.	.408	.864	.0153
4000	1400.	221.	.359	.880	.0126	210.	.337	.888	.0107	199.	.318	.894	.0093
	1600.	272.	.390	.870	.0156	258.	.368	.877	.0134	246.	.348	.884	.0116
	1800.	324.	.419	.860	.0188	309.	.396	.868	.0162	295.	.375	.875	.0141
8.0	2000.	379.	.444	.852	.0222	362.	.421	.860	.0191	347.	.400	.867	.0167
	2400.	492.	.490	.837	.0294	472.	.466	.845	.0254	454.	.444	.852	.0222
5000	1750.	292.	.383	.872	.0168	278.	.361	.880	.0144	265.	.341	.886	.0124
	2000.	358.	.415	.862	.0208	341.	.392	.869	.0178	326.	.372	.876	.0155
	2250.	426.	.444	.852	.0250	407.	.421	.860	.0215	390.	.400	.867	.0187
7.1	2500.	496.	.470	.843	.0294	475.	.447	.851	.0254	456.	.425	.858	.0221
	3000.	641.	.516	.828	.0387	617.	.492	.836	.0335	595.	.470	.843	.0294
		f_s = 27,000		a = 2.00		f_s = 30,000		a = 2.24		f_s = 33,000		a = 2.48	
2500	875.	99.	.247	.918	.0040	92.	.228	.924	.0033	86.	.211	.930	.0028
	1000.	124.	.272	.909	.0050	115.	.252	.916	.0042	108.	.234	.922	.0036
	1125.	150.	.296	.901	.0062	140.	.275	.908	.0052	132.	.256	.915	.0044
10.1	1250.	178.	.319	.894	.0074	167.	.296	.901	.0062	157.	.277	.908	.0052
	1500.	237.	.359	.880	.0100	224.	.336	.888	.0084	211.	.315	.895	.0072
3000	1050.	126.	.264	.912	.0051	117.	.244	.919	.0043	110.	.226	.925	.0036
	1200.	157.	.290	.903	.0064	147.	.269	.910	.0054	138.	.251	.916	.0046
	1350.	190.	.315	.895	.0079	178.	.293	.902	.0066	168.	.273	.909	.0056
9.2	1500.	225.	.338	.887	.0094	211.	.315	.895	.0079	199.	.295	.902	.0067
	1800.	299.	.380	.873	.0127	282.	.356	.881	.0107	267.	.334	.889	.0091
4000	1400.	185.	.293	.902	.0076	173.	.272	.909	.0063	162.	.253	.916	.0054
	1600.	230.	.322	.893	.0095	215.	.299	.900	.0080	203.	.279	.907	.0068
	1800.	277.	.348	.884	.0116	260.	.324	.892	.0097	246.	.304	.899	.0083
8.0	2000.	326.	.372	.876	.0138	308.	.348	.884	.0116	291.	.327	.891	.0099
	2400.	430.	.416	.861	.0185	407.	.390	.870	.0156	387.	.368	.877	.0134
5000	1750.	247.	.315	.895	.0102	231.	.293	.902	.0085	218.	.274	.909	.0073
	2000.	305.	.345	.885	.0128	287.	.321	.893	.0107	271.	.301	.900	.0091
	2250.	366.	.372	.876	.0155	346.	.347	.884	.0130	327.	.326	.891	.0111
7.1	2500.	430.	.397	.868	.0184	407.	.372	.876	.0155	386.	.350	.883	.0132
	3000.	564.	.441	.853	.0245	537.	.415	.862	.0208	511.	.392	.869	.0178

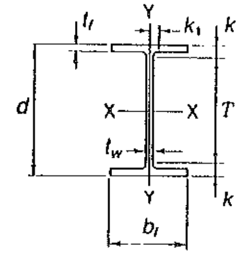
*"Balanced steel ratio" applies to problems involving bending only.



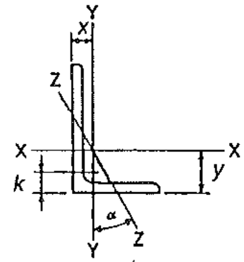
W SHAPES
Dimensions

Designation	Area A	Depth d		Web Thickness t_w		Web $\frac{t_w}{2}$	Flange Width b_f		Flange Thickness t_f		Distance T	Distance k	Distance k_1
	In.^{2}	In.		In.		In.	In.		In.		In.	In.	In.
W 8×67	19.7	9.00	9	0.570	9/16	5/16	8.280	8¼	0.935	15/16	6⅛	1 7/16	11/16
×58	17.1	8.75	8¾	0.510	½	¼	8.220	8¼	0.810	13/16	6⅛	1 5/16	11/16
×48	14.1	8.50	8½	0.400	⅜	3/16	8.110	8⅛	0.685	11/16	6⅛	1 3/16	⅝
×40	11.7	8.25	8¼	0.360	⅜	3/16	8.070	8⅛	0.560	9/16	6⅛	1 1/16	⅝
$\boxed{\times 35}$	$\boxed{10.3}$	8.12	8⅛	0.310	5/16	3/16	8.020	8	0.495	½	6⅛	1	9/16
×31	9.13	8.00	8	0.285	5/16	3/16	7.995	8	0.435	7/16	6⅛	15/16	9/16
W 8×28	8.25	8.06	8	0.285	5/16	3/16	6.535	6½	0.465	7/16	6⅛	15/16	9/16
×24	7.08	7.93	7⅞	0.245	¼	⅛	6.495	6½	0.400	⅜	6⅛	⅞	9/16
W 8×21	6.16	8.28	8¼	0.250	¼	⅛	5.270	5¼	0.400	⅜	6⅝	13/16	½
×18	5.26	8.14	8⅛	0.230	¼	⅛	5.250	5¼	0.330	5/16	6⅝	¾	7/16
W 8×15	4.44	8.11	8⅛	0.245	¼	⅛	4.015	4	0.315	5/16	6⅝	¾	½
×13	3.84	7.99	8	0.230	¼	⅛	4.000	4	0.255	¼	6⅝	11/16	7/16
×10	2.96	7.89	7⅞	0.170	3/16	⅛	3.940	4	0.205	3/16	6⅝	⅝	7/16
W 6×25	7.34	6.38	6⅜	0.320	5/16	3/16	6.080	6⅛	0.455	7/16	4¾	13/16	7/16
$\boxed{\times 20}$	$\boxed{5.87}$	6.20	6¼	0.260	¼	⅛	6.020	6	0.365	⅜	4¾	¾	7/16
×15	4.43	5.99	6	0.230	¼	⅛	5.990	6	0.260	¼	4¾	⅝	⅜
$\boxed{\text{W 6×16}}$	$\boxed{4.74}$	6.28	6¼	0.260	¼	⅛	4.030	4	0.405	⅜	4¾	¾	7/16
×12	3.55	6.03	6	0.230	¼	⅛	4.000	4	0.280	¼	4¾	⅝	⅜
× 9	2.68	5.90	5⅞	0.170	3/16	⅛	3.940	4	0.215	3/16	4¾	9/16	⅜
W 5×19	5.54	5.15	5⅛	0.270	¼	⅛	5.030	5	0.430	7/16	3½	13/16	7/16
×16	4.68	5.01	5	0.240	¼	⅛	5.000	5	0.360	⅜	3½	¾	7/16
W 4×13	3.83	4.16	4⅛	0.280	¼	⅛	4.060	4	0.345	⅜	2¾	11/16	7/16

W SHAPES
Properties



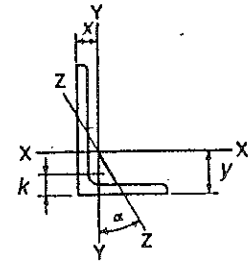
Nominal Wt. per Ft	Compact Section Criteria $\frac{b_f}{2t_f}$	Compact Section Criteria F_y'	Compact Section Criteria $\frac{d}{t_w}$	Compact Section Criteria F_y'''	r_T	$\frac{d}{A_f}$	Elastic Properties Axis X-X I	Axis X-X S	Axis X-X r	Axis Y-Y I	Axis Y-Y S	Axis Y-Y r	Plastic Modulus Z_x	Plastic Modulus Z_y
Lb.		Ksi		Ksi	In.		In.^{4}	In.^{3}	In.	In.^{4}	In.^{3}	In.	In.^{3}	In.^{3}
67	4.4	—	15.8	—	2.28	1.16	272	60.4	3.72	88.6	21.4	2.12	70.2	32.7
58	5.1	—	17.2	—	2.26	1.31	228	52.0	3.65	75.1	18.3	2.10	59.8	27.9
48	5.9	—	21.3	—	2.23	1.53	184	43.3	3.61	60.9	15.0	2.08	49.0	22.9
40	7.2	—	22.9	—	2.21	1.83	146	35.5	3.53	49.1	12.2	2.04	39.8	18.5
35	8.1	64.4	26.2	—	2.20	2.05	127	31.2	3.51	42.6	10.6	$\boxed{2.03}$	34.7	16.1
31	9.2	50.0	28.1	—	2.18	2.30	110	27.5	3.47	37.1	9.27	2.02	30.4	14.1
28	7.0	—	28.3	—	1.77	2.65	98.0	24.3	3.45	21.7	6.63	1.62	27.2	10.1
24	8.1	64.1	32.4	63.0	1.76	3.05	82.8	20.9	3.42	18.3	5.63	1.61	23.2	8.57
21	6.6	—	33.1	60.2	1.41	3.93	75.3	18.2	3.49	9.77	3.71	1.26	20.4	5.69
18	8.0	—	35.4	52.7	1.39	4.70	61.9	15.2	3.43	7.97	3.04	1.23	17.0	4.66
15	6.4	—	33.1	60.3	1.03	6.41	48.0	11.8	3.29	3.41	1.70	0.876	13.6	2.67
13	7.8	—	34.7	54.7	1.01	7.83	39.6	9.91	3.21	2.73	1.37	0.843	11.4	2.15
10	9.6	45.8	46.4	30.7	0.99	9.77	30.8	7.81	3.22	2.09	1.06	0.841	8.87	1.66
25	6.7	—	19.9	—	1.66	2.31	53.4	16.7	2.70	17.1	5.61	1.52	18.9	8.56
20	8.2	62.1	23.8	—	1.64	2.82	41.4	13.4	2.66	13.3	4.41	$\boxed{1.50}$	14.9	6.72
15	11.5	31.8	26.0	—	1.61	3.85	29.1	9.72	2.56	9.32	3.11	1.46	10.8	4.75
16	5.0	—	24.2	—	1.08	3.85	32.1	10.2	2.60	4.43	2.20	$\boxed{0.966}$	11.7	3.39
12	7.1	—	26.2	—	1.05	5.38	22.1	7.31	2.49	2.99	1.50	0.918	8.30	2.32
9	9.2	50.3	34.7	54.8	1.03	6.96	16.4	5.56	2.47	2.19	1.11	0.905	6.23	1.72
19	5.8	—	19.1	—	1.38	2.38	26.2	10.2	2.17	9.13	3.63	1.28	11.6	5.53
16	6.9	—	20.9	—	1.37	2.78	21.3	8.51	2.13	7.51	3.00	1.27	9.59	4.57
13	5.9	—	14.9	—	1.10	2.97	11.3	5.46	1.72	3.86	1.90	1.00	6.28	2.92



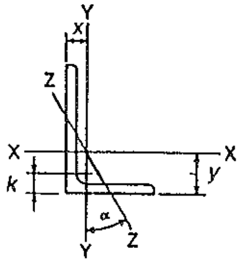
ANGLES
Equal legs and unequal legs
Properties for designing

Size and Thickness	k	Weight per Ft	Area	AXIS X-X				AXIS Y-Y				AXIS Z-Z	
				I	S	r	y	I	S	r	x	r	Tan α
In.	In.	Lb.	In.^{2}	In.^{4}	In.^{3}	In.	In.	In.^{4}	In.^{3}	In.	In.	In.	
L 9×4× 5/8	1 1/8	26.3	7.73	64.9	11.5	2.90	3.36	8.32	2.65	1.04	0.858	.847	0.216
9/16	1 1/16	23.8	7.00	59.1	10.4	2.91	3.33	7.63	2.41	1.04	0.834	.850	0.218
1/2	1	21.3	6.25	53.2	9.34	2.92	3.31	6.92	2.17	1.05	0.810	.854	0.220
L 8×8×1 1/8	1 3/4	56.9	16.7	98.0	17.5	2.42	2.41	98.0	17.5	2.42	2.41	1.56	1.000
1	1 5/8	51.0	15.0	89.0	15.8	2.44	2.37	89.0	15.8	2.44	2.37	1.56	1.000
7/8	1 1/2	45.0	13.2	79.6	14.0	2.45	2.32	79.6	14.0	2.45	2.32	1.57	1.000
3/4	1 3/8	38.9	11.4	69.7	12.2	2.47	2.28	69.7	12.2	2.47	2.28	1.58	1.000
5/8	1 1/4	32.7	9.61	59.4	10.3	2.49	2.23	59.4	10.3	2.49	2.23	1.58	1.000
9/16	1 3/16	29.6	8.68	54.1	9.34	2.50	2.21	54.1	9.34	2.50	2.21	1.59	1.000
1/2	1 1/8	26.4	7.75	48.6	8.36	2.50	2.19	48.6	8.36	2.50	2.19	1.59	1.000
L 8×6×1	1 1/2	44.2	13.0	80.8	15.1	2.49	2.65	38.8	8.92	1.73	1.65	1.28	0.543
7/8	1 3/8	39.1	11.5	72.3	13.4	2.51	2.61	34.9	7.94	1.74	1.61	1.28	0.547
3/4	1 1/4	33.8	9.94	63.4	11.7	2.53	2.56	30.7	6.92	1.76	1.56	1.29	0.551
5/8	1 1/8	28.5	8.36	54.1	9.87	2.54	2.52	26.3	5.88	1.77	1.52	1.29	0.554
9/16	1 1/16	25.7	7.56	49.3	8.95	2.55	2.50	24.0	5.34	1.78	1.50	1.30	0.556
1/2	1	23.0	6.75	44.3	8.02	2.56	2.47	21.7	4.79	1.79	1.47	1.30	0.558
7/16	15/16	20.2	5.93	39.2	7.07	2.57	2.45	19.3	4.23	1.80	1.45	1.31	0.560
L 8×4×1	1 1/2	37.4	11.0	69.6	14.1	2.52	3.05	11.6	3.94	1.03	1.05	0.846	0.247
3/4	1 1/4	28.7	8.44	54.9	10.9	2.55	2.95	9.36	3.07	1.05	0.953	0.852	0.258
9/16	1 1/16	21.9	6.43	42.8	8.35	2.58	2.88	7.43	2.38	1.07	0.882	0.861	0.265
1/2	1	19.6	5.75	38.5	7.49	2.59	2.86	6.74	2.15	1.08	0.859	0.865	0.267
L 7×4× 3/4	1 1/4	26.2	7.69	37.8	8.42	2.22	2.51	9.05	3.03	1.09	1.01	0.860	0.324
5/8	1 1/8	22.1	6.48	32.4	7.14	2.24	2.46	7.84	2.58	1.10	0.963	0.865	0.329
1/2	1	17.9	5.25	26.7	5.81	2.25	2.42	6.53	2.12	1.11	0.917	0.872	0.335
3/8	7/8	13.6	3.98	20.6	4.44	2.27	2.37	5.10	1.63	1.13	0.870	0.880	0.340

ANGLES
Equal legs and unequal legs
Properties for designing



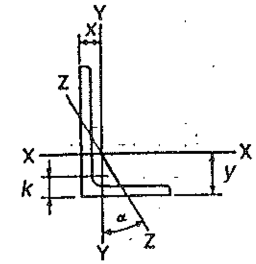
Size and Thickness	k	Weight per Ft	Area	AXIS X-X				AXIS Y-Y				AXIS Z-Z	
				I	S	r	y	I	S	r	x	r	Tan α
In.	In.	Lb.	In.^{2}	In.^{4}	In.^{3}	In.	In.	In.^{4}	In.^{3}	In.	In.	In.	α
L 6×6 ×1	1 1/2	37.4	11.0	35.5	8.57	1.80	1.86	35.5	8.57	1.80	1.86	1.17	1.000
7/8	1 3/8	33.1	9.73	31.9	7.63	1.81	1.82	31.9	7.63	1.81	1.82	1.17	1.000
3/4	1 1/4	28.7	8.44	28.2	6.66	1.83	1.78	28.2	6.66	1.83	1.78	1.17	1.000
5/8	1 1/8	24.2	7.11	24.2	5.66	1.84	1.73	24.2	5.66	1.84	1.73	1.18	1.000
9/16	1 1/16	21.9	6.43	22.1	5.14	1.85	1.71	22.1	5.14	1.85	1.71	1.18	1.000
1/2	1	19.6	5.75	19.9	4.61	1.86	1.68	19.9	4.61	1.86	1.68	1.18	1.000
7/16	15/16	17.2	5.06	17.7	4.08	1.87	1.66	17.7	4.08	1.87	1.66	1.19	1.000
3/8	7/8	14.9	4.36	15.4	3.53	1.88	1.64	15.4	3.53	1.88	1.64	1.19	1.000
5/16	13/16	12.4	3.65	13.0	2.97	1.89	1.62	13.0	2.97	1.89	1.62	1.20	1.000
L 6×4 × 7/8	1 3/8	27.2	7.98	27.7	7.15	1.86	2.12	9.75	3.39	1.11	1.12	0.857	0.421
3/4	1 1/4	23.6	6.94	24.5	6.25	1.88	2.08	8.68	2.97	1.12	1.08	0.860	0.428
5/8	1 1/8	20.0	5.86	21.1	5.31	1.90	2.03	7.52	2.54	1.13	1.03	0.864	0.435
9/16	1 1/16	18.1	5.31	19.3	4.83	1.90	2.01	6.91	2.31	1.14	1.01	0.866	0.438
1/2	1	16.2	4.75	17.4	4.33	1.91	1.99	6.27	2.08	1.15	0.987	0.870	0.440
7/16	15/16	14.3	4.18	15.5	3.83	1.92	1.96	5.60	1.85	1.16	0.964	0.873	0.443
3/8	7/8	12.3	3.61	13.5	3.32	1.93	1.94	4.90	1.60	1.17	0.941	0.877	0.446
5/16	13/16	10.3	3.03	11.4	2.79	1.94	1.92	4.18	1.35	1.17	0.918	0.882	0.448
L 6×3 1/2× 1/2	1	15.3	4.50	16.6	4.24	1.92	2.08	4.25	1.59	0.972	0.833	0.759	0.344
3/8	7/8	11.7	3.42	12.9	3.24	1.94	2.04	3.34	1.23	0.988	0.787	0.767	0.350
5/16	13/16	9.8	2.87	10.9	2.73	1.95	2.01	2.85	1.04	0.996	0.763	0.772	0.352
L 5×5 × 7/8	1 3/8	27.2	7.98	17.8	5.17	1.49	1.57	17.8	5.17	1.49	1.57	0.973	1.000
3/4	1 1/4	23.6	6.94	15.7	4.53	1.51	1.52	15.7	4.53	1.51	1.52	0.975	1.000
5/8	1 1/8	20.0	5.86	13.6	3.86	1.52	1.48	13.6	3.86	1.52	1.48	0.978	1.000
1/2	1	16.2	4.75	11.3	3.16	1.54	1.43	11.3	3.16	1.54	1.43	0.983	1.000
7/16	15/16	14.3	4.18	10.0	2.79	1.55	1.41	10.0	2.79	1.55	1.41	0.986	1.000
3/8	7/8	12.3	3.61	8.74	2.42	1.56	1.39	8.74	2.42	1.56	1.39	0.990	1.000
5/16	13/16	10.3	3.03	7.42	2.04	1.57	1.37	7.42	2.04	1.57	1.37	0.994	1.000



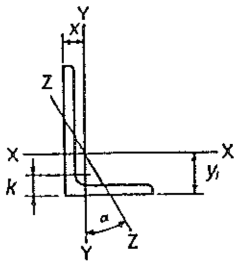
ANGLES
Equal legs and unequal legs
Properties for designing

Size and Thickness	k	Weight per Ft	Area	AXIS X-X				AXIS Y-Y				AXIS Z-Z	
				I	*S*	*r*	*y*	*I*	*S*	*r*	*x*	*r*	Tan α
In.	In.	Lb.	In.^{2}	In.^{4}	In.^{3}	In.	In.	In.^{4}	In.^{3}	In.	In.	In.	
L 5×3½× ¾	1¼	19.8	5.81	13.9	4.28	1.55	1.75	5.55	2.22	0.977	0.996	0.748	0.464
⅝	1⅛	16.8	4.92	12.0	3.65	1.56	1.70	4.83	1.90	0.991	0.951	0.751	0.472
½	1	13.6	4.00	9.99	2.99	1.58	1.66	4.05	1.56	1.01	0.906	0.755	0.479
7/16	15/16	12.0	3.53	8.90	2.64	1.59	1.63	3.63	1.39	1.01	0.883	0.758	0.482
⅜	⅞	10.4	3.05	7.78	2.29	1.60	1.61	3.18	1.21	1.02	0.861	0.762	0.486
5/16	13/16	8.7	2.56	6.60	1.94	1.61	1.59	2.72	1.02	1.03	0.838	0.766	0.489
¼	¾	7.0	2.06	5.39	1.57	1.62	1.56	2.23	0.830	1.04	0.814	0.770	0.492
L 5×3 × ⅝	1	15.7	4.61	11.4	3.55	1.57	1.80	3.06	1.39	0.815	0.796	0.644	0.349
½	1	12.8	3.75	9.45	2.91	1.59	1.75	2.58	1.15	0.829	0.750	0.648	0.357
7/16	15/16	11.3	3.31	8.43	2.58	1.60	1.73	2.32	1.02	0.837	0.727	0.651	0.361
⅜	⅞	9.8	2.86	7.37	2.24	1.61	1.70	2.04	0.888	0.845	0.704	0.654	0.364
5/16	13/16	8.2	2.40	6.26	1.89	1.61	1.68	1.75	0.753	0.853	0.681	0.658	0.368
¼	¾	6.6	1.94	5.11	1.53	1.62	1.66	1.44	0.614	0.861	0.657	0.663	0.371
L 4×4 × ¾	1⅛	18.5	5.44	7.67	2.81	1.19	1.27	7.67	2.81	1.19	1.27	0.778	1.000
⅝	1	15.7	4.61	6.66	2.40	1.20	1.23	6.66	2.40	1.20	1.23	0.779	1.000
½	⅞	12.8	3.75	5.56	1.97	1.22	1.18	5.56	1.97	1.22	1.18	0.782	1.000
7/16	13/16	11.3	3.31	4.97	1.75	1.23	1.16	4.97	1.75	1.23	1.16	0.785	1.000
⅜	¾	9.8	2.86	4.36	1.52	1.23	1.14	4.36	1.52	1.23	1.14	0.788	1.000
5/16	11/16	8.2	2.40	3.71	1.29	1.24	1.12	3.71	1.29	1.24	1.12	0.791	1.000
¼	⅝	6.6	1.94	3.04	1.05	1.25	1.09	3.04	1.05	1.25	1.09	0.795	1.000
L 4×3½× ½	15/16	11.9	3.50	5.32	1.94	1.23	1.25	3.79	1.52	1.04	1.00	0.722	0.750
7/16	⅞	10.6	3.09	4.76	1.72	1.24	1.23	3.40	1.35	1.05	0.978	0.724	0.753
⅜	13/16	9.1	2.67	4.18	1.49	1.25	1.21	2.95	1.17	1.06	0.955	0.727	0.755
5/16	¾	7.7	2.25	3.56	1.26	1.26	1.18	2.55	0.994	1.07	0.932	0.730	0.757
¼	11/16	6.2	1.81	2.91	1.03	1.27	1.16	2.09	0.808	1.07	0.909	0.734	0.759

ANGLES
Equal legs and unequal legs
Properties for designing



Size and Thickness	k	Weight per Ft	Area	AXIS X-X				AXIS Y-Y				AXIS Z-Z	
				I	*S*	*r*	*y*	*I*	*S*	*r*	*x*	*r*	Tan α
In.	In.	Lb.	In.^{2}	In.^{4}	In.^{3}	In.	In.	In.^{4}	In.^{3}	In.	In.	In.	
L 4 ×3 × ½	15/16	11.1	3.25	5.05	1.89	1.25	1.33	2.42	1.12	0.864	0.827	0.639	0.543
7/16	⅞	9.8	2.87	4.52	1.68	1.25	1.30	2.18	0.992	0.871	0.804	0.641	0.547
⅜	13/16	8.5	2.48	3.96	1.46	1.26	1.28	1.92	0.866	0.879	0.782	0.644	0.551
5/16	¾	7.2	2.09	3.38	1.23	1.27	1.26	1.65	0.734	0.887	0.759	0.647	0.554
¼	11/16	5.8	1.69	2.77	1.00	1.28	1.24	1.36	0.599	0.896	0.736	0.651	0.558
L 3½×3½× ½	⅞	11.1	3.25	3.64	1.49	1.06	1.06	3.64	1.49	1.06	1.06	0.683	1.000
7/16	13/16	9.8	2.87	3.26	1.32	1.07	1.04	3.26	1.32	1.07	1.04	0.684	1.000
⅜	¾	8.5	2.48	2.87	1.15	1.07	1.01	2.87	1.15	1.07	1.01	0.687	1.000
5/16	11/16	7.2	2.09	2.45	0.976	1.08	0.990	2.45	0.976	1.08	0.990	0.690	1.000
¼	⅝	5.8	1.69	2.01	0.794	1.09	0.968	2.01	0.794	1.09	0.968	0.694	1.000
L 3½×3 × ½	15/16	10.2	3.00	3.45	1.45	1.07	1.13	2.33	1.10	0.881	0.875	0.621	0.714
7/16	⅞	9.1	2.65	3.10	1.29	1.08	1.10	2.09	0.975	0.889	0.853	0.622	0.718
⅜	13/16	7.9	2.30	2.72	1.13	1.09	1.08	1.85	0.851	0.897	0.830	0.625	0.721
5/16	¾	6.6	1.93	2.33	0.954	1.10	1.06	1.58	0.722	0.905	0.808	0.627	0.724
¼	11/16	5.4	1.56	1.91	0.776	1.11	1.04	1.30	0.589	0.914	0.785	0.631	0.727
L 3½×2½× ½	15/16	9.4	2.75	3.24	1.41	1.09	1.20	1.36	0.760	0.704	0.705	0.534	0.486
7/16	⅞	8.3	2.43	2.91	1.26	1.09	1.18	1.23	0.677	0.711	0.682	0.535	0.491
⅜	13/16	7.2	2.11	2.56	1.09	1.10	1.16	1.09	0.592	0.719	0.660	0.537	0.496
5/16	¾	6.1	1.78	2.19	0.927	1.11	1.14	0.939	0.504	0.727	0.637	0.540	0.501
¼	11/16	4.9	1.44	1.80	0.755	1.12	1.11	0.777	0.412	0.735	0.614	0.544	0.506
L 3 ×3 × ½	13/16	9.4	2.75	2.22	1.07	0.898	0.932	2.22	1.07	0.898	0.932	0.584	1.000
7/16	¾	8.3	2.43	1.99	0.954	0.905	0.910	1.99	0.954	0.905	0.910	0.585	1.000
⅜	11/16	7.2	2.11	1.76	0.833	0.913	0.888	1.76	0.833	0.913	0.888	0.587	1.000
5/16	⅝	6.1	1.78	1.51	0.707	0.922	0.865	1.51	0.707	0.922	0.865	0.589	1.000
¼	9/16	4.9	1.44	1.24	0.577	0.930	0.842	1.24	0.577	0.930	0.842	0.592	1.000
3/16	½	3.71	1.09	0.962	0.441	0.939	0.820	0.962	0.441	0.939	0.820	0.596	1.000



ANGLES
Equal legs and unequal legs
Properties for designing

Size and Thickness	k	Weight per Ft	Area	AXIS X-X				AXIS Y-Y				AXIS Z-Z	
				I	S	r	y	I	S	r	x	r	Tan α
In.	In.	Lb.	In.^{2}	In.^{4}	In.^{3}	In.	In.	In.^{4}	In.^{3}	In.	In.	In.	
L 3 ×2½× ½	7/8	8.5	2.50	2.08	1.04	0.913	1.00	1.30	0.744	0.722	0.750	0.520	0.667
7/16	13/16	7.6	2.21	1.88	0.928	0.920	0.978	1.18	0.664	0.729	0.728	0.521	0.672
3/8	3/4	6.6	1.92	1.66	0.810	0.928	0.956	1.04	0.581	0.736	0.706	0.522	0.676
5/16	11/16	5.6	1.62	1.42	0.688	0.937	0.933	0.898	0.494	0.744	0.683	0.525	0.680
1/4	5/8	4.5	1.31	1.17	0.561	0.945	0.911	0.743	0.404	0.753	0.661	0.528	0.684
3/16	9/16	3.39	0.996	0.907	0.430	0.954	0.888	0.577	0.310	0.761	0.638	0.533	0.688
L 3 ×2 × ½	13/16	7.7	2.25	1.92	1.00	0.924	1.08	0.672	0.474	0.546	0.583	0.428	0.414
7/16	3/4	6.8	2.00	1.73	0.894	0.932	1.06	0.609	0.424	0.553	0.561	0.429	0.421
3/8	11/16	5.9	1.73	1.53	0.781	0.940	1.04	0.543	0.371	0.559	0.539	0.430	0.428
5/16	5/8	5.0	1.46	1.32	0.664	0.948	1.02	0.470	0.317	0.567	0.516	0.432	0.435
1/4	9/16	4.1	1.19	1.09	0.542	0.957	0.993	0.392	0.260	0.574	0.493	0.435	0.440
3/16	1/2	3.07	0.902	0.842	0.415	0.966	0.970	0.307	0.200	0.583	0.470	0.439	0.446
L 2½×2½× ½	13/16	7.7	2.25	1.23	0.724	0.739	0.806	1.23	0.724	0.739	0.806	0.487	1.000
3/8	11/16	5.9	1.73	0.984	0.566	0.753	0.762	0.984	0.566	0.753	0.762	0.487	1.000
5/16	5/8	5.0	1.46	0.849	0.482	0.761	0.740	0.849	0.482	0.761	0.740	0.489	1.000
1/4	9/16	4.1	1.19	0.703	0.394	0.769	0.717	0.703	0.394	0.769	0.717	0.491	1.000
3/16	1/2	3.07	0.902	0.547	0.303	0.778	0.694	0.547	0.303	0.778	0.694	0.495	1.000
L 2½×2 × 3/8	11/16	5.3	1.55	0.912	0.547	0.768	0.831	0.514	0.363	0.577	0.581	0.420	0.614
5/16	5/8	4.5	1.31	0.788	0.466	0.776	0.809	0.446	0.310	0.584	0.559	0.422	0.620
1/4	9/16	3.62	1.06	0.654	0.381	0.784	0.787	0.372	0.254	0.592	0.537	0.424	0.626
3/16	1/2	2.75	0.809	0.509	0.293	0.793	0.764	0.291	0.196	0.600	0.514	0.427	0.631
L 2 ×2 × 3/8	5/8	4.7	1.36	0.479	0.351	0.594	0.636	0.479	0.351	0.594	0.636	0.389	1.000
5/16	9/16	3.92	1.15	0.416	0.300	0.601	0.614	0.416	0.300	0.601	0.614	0.390	1.000
$\boxed{1/4}$	1/2	$\boxed{3.19}$	0.938	0.348	0.247	0.609	0.592	0.348	0.247	0.609	0.592	0.391	1.000
3/16	7/16	2.44	0.715	0.272	0.190	0.617	0.569	0.272	0.190	0.617	0.569	0.394	1.000
1/8	3/8	1.65	0.484	0.190	0.131	0.626	0.546	0.190	0.131	0.626	0.546	0.398	1.000

Table C-36
Allowable Stress
For Compression Members of 36-ksi Specified Yield Stress Steel[a]

$F_y = 36$ ksi

$\frac{Kl}{r}$	F_a (ksi)	$\frac{Kl}{r}$	F_a (ksi)	$\frac{Kl}{r}$	F_a (ksi)	$\frac{Kl}{r}$	F_a (ksi)	$\frac{Kl}{r}$	F_a (ksi)
1	21.56	41	19.11	81	15.24	121	10.14	161	5.76
2	21.52	42	19.03	82	15.13	122	9.99	162	5.69
3	21.48	43	18.95	83	15.02	123	9.85	163	5.62
4	21.44	44	18.86	84	14.90	124	9.70	164	5.55
5	21.39	45	18.78	85	14.79	125	9.55	165	5.49
6	21.35	46	18.70	86	14.67	126	9.41	166	5.42
7	21.30	47	18.61	87	14.56	127	9.26	167	5.35
8	21.25	48	18.53	88	14.44	128	9.11	168	5.29
9	21.21	49	18.44	89	14.32	129	8.97	169	5.23
10	21.16	50	18.35	90	14.20	130	8.84	170	5.17
11	21.10	51	18.26	91	14.09	131	8.70	171	5.11
12	21.05	52	18.17	92	13.97	132	8.57	172	5.05
13	21.00	53	18.08	93	13.84	133	8.44	173	4.99
14	20.95	54	17.99	94	13.72	134	8.32	174	4.93
15	20.89	55	17.90	95	13.60	135	8.19	175	4.88
16	20.83	56	17.81	96	13.48	136	8.07	176	4.82
17	20.78	57	17.71	97	13.35	137	7.96	177	4.77
18	20.72	58	17.62	98	13.23	138	7.84	178	4.71
19	20.66	59	17.53	99	13.10	139	7.73	179	4.66
20	20.60	60	17.43	100	12.98	140	7.62	180	4.61
21	20.54	61	17.33	101	12.85	141	7.51	181	4.56
22	20.48	62	17.24	102	12.72	142	7.41	182	4.51
23	20.41	63	17.14	103	12.59	143	7.30	183	4.46
24	20.35	64	17.04	104	12.47	144	7.20	184	4.41
25	20.28	65	16.94	105	12.33	145	7.10	185	4.36
26	20.22	66	16.84	106	12.20	146	7.01	186	4.32
27	20.15	67	16.74	107	12.07	147	6.91	187	4.27
28	20.08	68	16.64	108	11.94	148	6.82	188	4.23
29	20.01	69	16.53	109	11.81	149	6.73	189	4.18
30	19.94	70	16.43	110	11.67	150	6.64	190	4.14
31	19.87	71	16.33	111	11.54	151	6.55	191	4.09
32	19.80	72	16.22	112	11.40	152	6.46	192	4.05
33	19.73	73	16.12	113	11.26	153	6.38	193	4.01
34	19.65	74	16.01	114	11.13	154	6.30	194	3.97
35	19.58	75	15.90	115	10.99	155	6.22	195	3.93
36	19.50	76	15.79	116	10.85	156	6.14	196	3.89
37	19.42	77	15.69	117	10.71	157	6.06	197	3.85
38	19.35	78	15.58	118	10.57	158	5.98	198	3.81
39	19.27	79	15.47	119	10.43	159	5.91	199	3.77
40	19.19	80	15.36	120	10.28	160	5.83	200	3.73

[a]When element width-to-thickness ratio exceeds noncompact section limits of Sect. B5.1, see Appendix B5.
Note: $C_c = 126.1$

17 5

BOLTS, THREADED PARTS AND RIVETS
Tension
Allowable loads in kips

TABLE I-A. BOLTS AND RIVETS
Tension on gross (nominal) area

ASTM Designation	F_t Ksi	Nominal Diameter d, In.							
		5/8	3/4	7/8	1	1 1/8	1 1/4	1 3/8	1 1/2
		Area (Based on Nominal Diameter), In.^{2}							
		0.3068	0.4418	0.6013	0.7854	0.9940	1.227	1.485	1.767
A307 bolts	20.0	6.1	8.8	12.0	15.7	19.9	24.5	29.7	35.3
A325 bolts	44.0	13.5	19.4	26.5	34.6	43.7	54.0	65.3	77.7
A490 bolts	54.0	16.6	23.9	32.5	42.4	53.7	66.3	80.2	95.4
A502-1 rivets	23.0	7.1	10.2	13.8	18.1	22.9	28.2	34.2	40.6
A502-2,3 rivets	29.0	8.9	12.8	17.4	22.8	28.8	35.6	43.1	51.2

The above table lists ASTM specified materials that generally are intended for use as structural fasteners.
For dynamic and fatigue loading, only A325 or A490 high-strength bolts should be specified. See AISC Specification. Appendix K4.
For allowable combined shear and tension loads, see AISC ASD Specification Sects. J3.5 and J3.6.

TABLE I-B. THREADED FASTENERS
Tension on gross (nominal) area

ASTM Designation	F_y Ksi	F_u ksi	F_t ksi	Nominal Diameter d, In.							
				5/8	3/4	7/8	1	1 1/8	1 1/4	1 3/8	1 1/2
				Area (Based on Nominal Diameter), In.^{2}							
				0.3068	0.4418	0.6013	0.7854	0.9940	1.227	1.485	1.767
A36	36	58	19.1	5.9	$\boxed{8.4}$	11.5	$\boxed{15.0}$	19.0	23.4	28.4	33.7
A572, Gr. 50	50	65	21.5	6.6	9.5	12.9	16.9	21.4	26.4	31.9	38.0
A588	50	70	23.1	7.1	10.2	13.9	18.1	23.0	28.3	34.3	40.8
A449											
$d \leq 1$	92	120	39.6	12.1	17.5	23.8	31.1	—	—	—	—
$1 < d \leq 1\frac{1}{2}$	81	105	34.7	—	—	—	—	34.5	42.6	51.5	61.3

The above table lists ASTM specified materials available in round bar stock that are generally intended for use in threaded applications such as tie rods, cross bracing and similar uses. The tensile capacity of the threaded portion of an upset rod shall be larger than the body area times $0.6F_y$.
F_u = specified minimum tensile strength of the fastener material.
$F_t = 0.33F_u$ = allowable tensile stress in threaded fastener.

[17] 6

CHAPTER E

COLUMNS AND OTHER COMPRESSION MEMBERS

This section applies to prismatic members with compact and noncompact sections subject to axial compression through the centroidal axis. For members with slender elements, see Appendix B5.2. For members subject to combined axial compression and flexure, see Chap. H. For tapered members, see Appendix F7.

E1. EFFECTIVE LENGTH AND SLENDERNESS RATIO

The effective-length factor K shall be determined in accordance with Sect. C2.

In determining the slenderness ratio of an axially loaded compression member, the length shall be taken as its effective length Kl and r as the corresponding radius of gyration. For limiting slenderness ratios, see Sect. B7.

E2. ALLOWABLE STRESS

On the gross section of axially loaded compression members whose cross sections meet the provisions of Table B5.1, when Kl/r, the largest effective slenderness ratio of any unbraced segment is less than C_c, the allowable stress is:

$$F_a = \frac{\left[1 - \frac{(Kl/r)^2}{2C_c^2}\right] F_y}{\frac{5}{3} + \frac{3(Kl/r)}{8C_c} - \frac{(Kl/r)^3}{8C_c^3}} \qquad \text{(E2-1)}$$

where

$$C_c = \sqrt{\frac{2\pi^2 E}{F_y}}$$

On the gross section of axially loaded compression members, when Kl/r exceeds C_c, the allowable stress is:

$$F_a = \frac{12\pi^2 E}{23(Kl/r)^2} \qquad \text{(E2-2)}$$

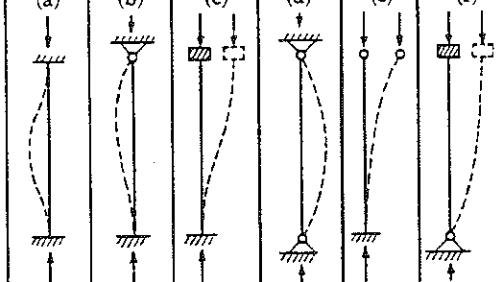
E3. FLEXURAL-TORSIONAL BUCKLING

Singly symmetric and unsymmetric columns, such as angles or tee-shaped columns, and doubly symmetric columns such as cruciform or built-up columns with very thin walls, may require consideration of flexural-torsional and torsional buckling.

the top of the column. On the other hand, the restraining influence of foundations, even where these footings are designed only for vertical load, can be very substantial in the case of flat-ended column base details with ordinary anchorage (Stang and Jaffe, 1948). For this condition, a design K-value of 1.5 would generally be conservative in Case f.

While in some cases the existence of masonry walls provides enough lateral support for their building frames to control lateral deflection, the increasing use of light curtain wall construction and wide column spacing for high-rise structures not provided with a positive system of diagonal bracing can create a situation where only the bending stiffness of the frame itself provides this support.

Table C-C2.1

	(a)	(b)	(c)	(d)	(e)	(f)
Buckled shape of column is shown by dashed line						
Theoretical K value	0.5	0.7	$\boxed{1.0}$	$\boxed{1.0}$	2.0	$\boxed{2.0}$
Recommended design value when ideal conditions are approximated	0.65	0.80	1.2	1.0	2.10	2.0
End condition code		Rotation fixed and translation fixed Rotation free and translation fixed Rotation fixed and translation free Rotation free and translation free				

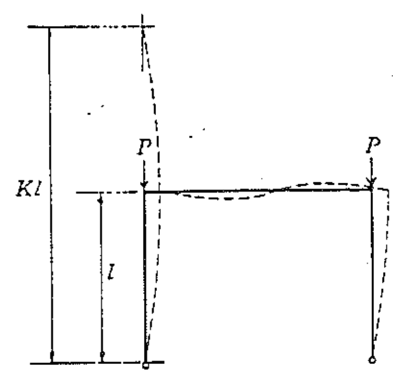
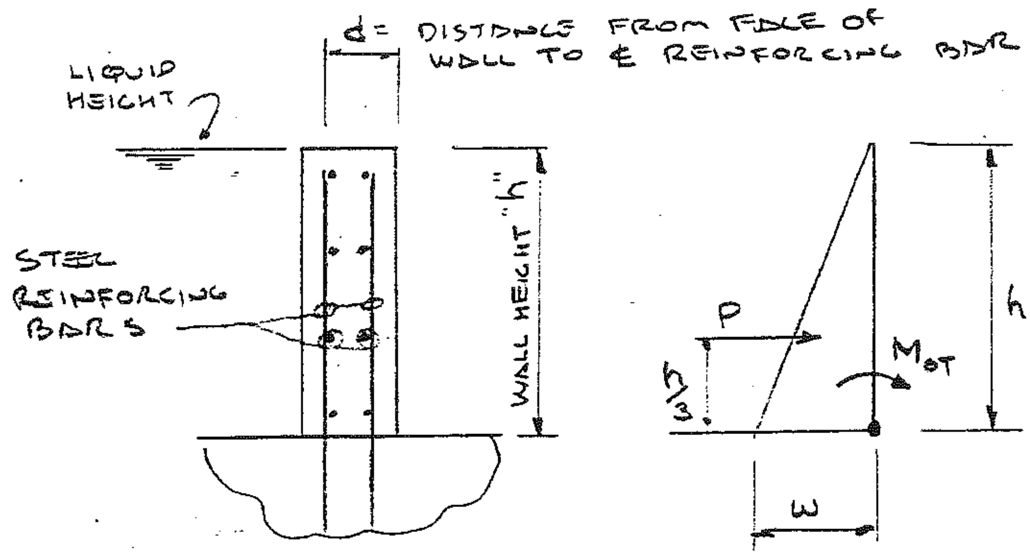


Figure C-C2.1

[17]

EQUASIONS FOR RETAINING WALL DESIGN



$\omega = \gamma\, h$

ω = FORCE AT BASE OF WALL (lb / FT)

γ = WEIGHT OF CONTAINED LIQUID (lb / CU. FT.)

h = HEIGHT OF CONTAINED LIQUID (FT)

$P = \omega \times \frac{1}{2} h = \omega h \times \frac{1}{2} h = \frac{1}{2} \omega h^2$

P = RESULTANT FORCE OF CONTAINED LIQUID

$M_{OT} = P \times \frac{1}{3} h$

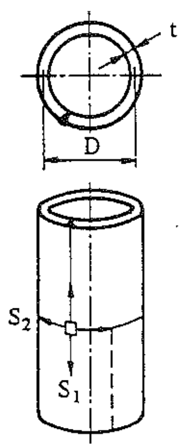
M = OVERTURNING MOMENT AT BASE OF WALL

STRESSES IN CYLINDRICAL SHELL

Uniform internal or external pressure induces in the longitudinal seam a unit stress two times larger than in the circumferential seam because of the geometry of the cylinder.

A vessel under external pressure, when other forces (wind, earthquake, etc.) are not factors, must be designed to resist the circumferential buckling only. The Code provides the method of design to meet this requirement. When other loadings are present, these combined loadings may govern and heavier plate will be required than the plate which was satisfactory to resist the circumferential buckling only.

The formulas below give the compression stress due to external pressure and tension stress due to internal pressure.



FORMULAS

CIRCUMFERENTIAL JOINT	LONGITUDINAL JOINT
$S_1 = \dfrac{PD}{4t}$	$S_2 = \dfrac{PD}{2t}$

NOTATION

D = Mean diameter of vessel, inches
P = Internal or external pressure, psi
S_1 = Longitudinal stress, psi
S_2 = Circumferential (hoop) stress, psi
t = Thickness of shell, corrosion allowance excluded, inches

EXAMPLE

Given D = 96 inches
P = 15 psi
t = 0.25 inches

$$S_1 = \frac{PD}{4t} = \frac{15 \times 96}{4 \times 0.25} = 1440 \text{ psi}$$

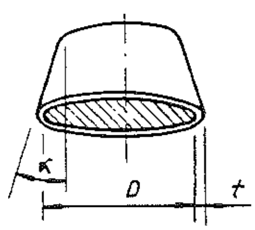
$$S_2 = \frac{PD}{2t} = \frac{15 \times 96}{2 \times 0.25} = 2880 \text{ psi}$$

INTERNAL PRESSURE

FORMULAS IN TERMS OF INSIDE DIMENSIONS

P = DESIGN PRESSURE OR MAX. ALLOWABLE WORKING PRESSURE PSI.
S = STRESS VALUE OF MATERIAL PSI. PAGE 126
E = JOINT EFFICIENCY, PAGE 112
R = INSIDE RADIUS, INCHES
D = INSIDE DIAMETER, INCHES
α = ONE HALF OF THE INCLUDED (APEX) ANGLE, DEGREES
L = INSIDE RADIUS OF DISH, INCHES
r = INSIDE KNUCKLE RADIUS, INCHES
t = WALL THICKNESS, INCHES
C.A. = CORROSION ALLOWANCE, INCHES

D



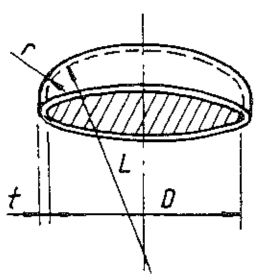
CONE AND CONICAL SECTION

$$t = \frac{PD}{2\cos\alpha\,(SE - 0.6P)}$$

$$P = \frac{2\,SE\,t\cos\alpha}{D + 1.2t\cos\alpha}$$

1. The half apex angle, α not greater than 30°

E



ASME FLANGED AND DISHED HEAD
(TORISPHERICAL HEAD)

When $L/r = 16\frac{2}{3}$

$$t = \frac{0.885\,PL}{SE - 0.1P}$$

$$P = \frac{SE\,t}{0.885L + 0.1t}$$

When L/r less than $16\frac{2}{3}$

$$t = \frac{PLM}{2SE - 0.2P}$$

$$P = \frac{2\,SE\,t}{LM + 0.2t}$$

VALUES OF FACTOR "M"

L/r	1.00	1.25	1.50	1.75	2.00	2.25	2.50	2.75	3.00	3.25	3.50	4.00	4.50	5.00	5.50	6.00	6.50
M	1.00	1.03	1.06	1.08	1.10	1.13	1.15	1.17	1.18	1.20	1.22	1.25	1.28	1.31	1.34	1.36	1.39
L/r	7.00	7.50	8.00	8.50	9.00	9.50	10.0	10.5	11.0	11.5	12.0	13.0	14.0	15.0	16.0	$16\frac{2}{3}$	*
M	1.41	1.44	1.46	1.48	1.50	1.52	1.54	1.56	1.58	1.60	1.62	1.65	1.69	1.72	1.75	1.77	

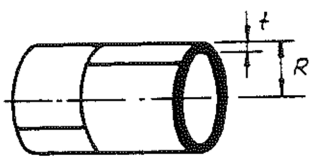
* THE MAXIMUM ALLOWED RATIO : L = D + 2t

INTERNAL PRESSURE

FORMULAS IN TERMS OF OUTSIDE DIMENSIONS

P = DESIGN PRESSURE OR MAX. ALLOWABLE WORKING PRESSURE PSI
S = STRESS VALUE OF MATERIAL PSI , PAGE 126
E = JOINT EFFICIENCY PAGE 112
R = OUTSIDE RADIUS, INCHES
D = OUTSIDE DIAMETER, INCHES
t = WALL THICKNESS, INCHES
C.A. = CORROSION ALLOWANCE, INCHES

A



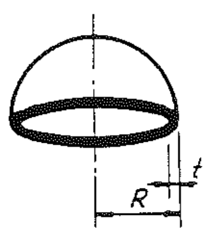
CYLINDRICAL SHELL (LONG SEAM)[1]

$$t = \frac{PR}{SE + 0.4P}$$

$$P = \frac{SEt}{R - 0.4t}$$

1. Usually the stress in the long seam is governing. See page 7.
2. When the wall thickness exceeds one half of the inside radius or P exceeds 0.385 SE, the formulas given in the code UA 2 shall be applied.

B



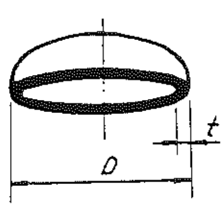
SPHERE and HEMISPHERICAL HEAD

$$t = \frac{PR}{2SE+0.8P}$$

$$P = \frac{2SEt}{R - 0.8t}$$

1. For heads without a straight flange, use the efficiency of the head to shell joint if it is less than the efficiency of the seams in the head.
2. When the wall thickness exceeds 0.356 R or P exceeds 0.665 SE, the formulas given in the code UA. 3. shall be applied.

C



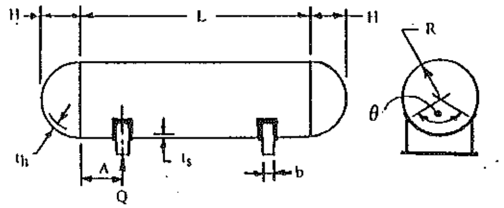
2:1 ELLIPSOIDAL HEAD

$$t = \frac{PD}{2SE+1.8P}$$

$$P = \frac{2SEt}{D - 1.8t}$$

1. For ellipsoidal heads, where the ratio of the major and minor axis is other than 2:1, see Code UA.4(C).

STRESSES IN VESSELS ON TWO SADDLES



NOTATION:
All dimensions in inches
Q = Load on one saddle lbs.
R = Radius of shell
S = Stress pound per sq. inch
t_s = Wall thickness of shell
t_h = Wall thickness of head (Excluding corrosion allow.)
K = Constant, see page 76.
θ = Contact angle of saddle degree

Stress	Conditions	Max. Stress Occurs	FORMULAS	Max. Allow. Stress
LONGITUDINAL BENDING	SHELL STIFFENED BY HEADS OR RINGS OR SHELL UNSTIFFENED	AT THE SADDLES (Tension at the Top, Compression at the Bottom)	$S_1 = \pm \dfrac{QA\left(1-\dfrac{1-\frac{A}{L}+\frac{R^2-H^2}{2AL}}{1+\frac{4H}{3L}}\right)}{{}^{*}KR^2 t_s}$ *See note on facing page	In tension S_1 plus the stress due to internal pressure ($PR/2t_s$) shall not exceed the allowable stress value of shell material times the efficiency of girth seam. In compression the stress due to internal pressure minus S_1 shall not exceed one half of the compression yield point of the material or the value given by: $S_1 \leqq \left(\frac{E}{29}\right)(t/R)[2-(2/3)(100)(t/R)]$
		AT MIDSPAN (Tension at the Top, Compression at the Bottom)	$S_1 = \pm \dfrac{\frac{QL}{4}\left(\dfrac{1+2\frac{R^2-H^2}{L^2}}{1+\frac{4H}{3L}}-\dfrac{4A}{L}\right)}{\pi R^2 t_s}$	
TANGENTIAL SHEAR	Saddles Away From Head A > R/2 See Note	IN SHELL	$S_2 = \dfrac{K_2 Q}{Rt_s}\left(\dfrac{L-2A}{L+4/3\,H}\right)$	S_2 shall not exceed 0.8 times the allowable stress value of vessel material. S_3 plus stress due to internal pressure shall not exceed 1.25 times the allowable tensile stress value of head material. NOTE: Use formula with factor K_2 if ring not used or rings are adjacent to the saddle. Use formula with factor K_3 if ring used in plane of saddle.
		IN SHELL	$S_2 = \dfrac{K_3 Q}{Rt_s}\left(\dfrac{L-2A}{L+4/3\,H}\right)$	
	SADDLES CLOSE TO HEAD A ≦ R/2	IN SHELL	$S_2 = \dfrac{K_4 Q}{Rt_s}$	
		IN HEAD	$S_2 = \dfrac{K_4 Q}{Rt_h}$	
		ADDITIONAL STRESS IN HEAD	$S_3 = \dfrac{K_5 Q}{Rt_h}$	
CIRCUMFERENTIAL	UNSTIFFENED L ≧ 8R	AT HORN OF SADDLE	$S_4 = -\dfrac{Q}{4t_s(b+1.56\sqrt{Rt_s})}-\dfrac{3K_6 Q}{2t_s^2}$	S_4 shall not exceed 1.50 times the allowable tensile stress value of shell material. S_5 shall not exceed 0.5 times the compression yield point of shell material.
	UNSTIFFENED L < 8R		$S_4 = -\dfrac{Q}{4t_s(b+1.56\sqrt{Rt_s})}-\dfrac{12K_6 QR}{Lt_s^2}$	
	Stiffened or Unstiffened	AT BOTTOM OF SHELL	$S_5 = -\dfrac{K_7 Q}{t_s(b+1.56\sqrt{Rt_s})}$	

STRESSES IN VESSELS ON TWO SADDLES

STRESS

NOTES:

Positive values denote tensile stresses and negative values denote compression.

E = Modulus of elasticity of shell or stiffener ring material pound per square inch.

LONGITUDINAL BENDING

The maximum bending stress S_1 may be either tension or compression.

Computing the tension stress in the formula for S_1, for factor K the values of K_1 shall be used.

Computing the compression stress in the formula for S_1, for factor K the values of K_8 shall be used.

When the shell is stiffened, the value of factor K = 3.14 in the formula for S_1.

The compression stress is not factor in a steel vessel where $t/R \geqq 0.005$ and the vessel is designed to be fully stressed under internal pressure.

Use stiffener ring if stress S_1 exceeds the maximum allowable stress.

TANGENTIAL SHEAR

If wear plate is used, in formulas for S_2 for the thickness t_s may be taken the sum of the shell and wear plate thickness, provided the wear plate extends R/10 inches above the horn of the saddle near the head and extends between the saddle and an adjacent stiffener ring.

In unstiffened shell the maximum shear occurs at the horn of the saddle. When the head stiffness is utilized by locating the saddle close to the heads, the tangential shear stress can cause an additional stress (S3) in the heads. This stress shall be added to the stress in the heads due to internal pressure.

When stiffener rings are used, the maximum shear occurs at the equator.

CIRCUMFERENTIAL

If wear plate is used, in formulas for S_4 for the thickness t_s may be taken the sum of the shell and wear plate thickness and for t_s^2 may be taken the shell thickness squared plus the wear plate thickness squared, provided the wear plate extends R/10 inches above the horn of the saddle near the head. The combined circumferential stress at the top edge of the wear plate should also be checked.
When checking at this point: t_s = shell thickness,
b = width of saddle
θ = central angle of the wear plate but not more than the included angle of the saddle plus 12°
If wear plate is used, in formulas for S_5 for the thickness t_s may be taken the sum of the shell and wear plate thickness, provided the width of the wear plate equals at least $b + 1.56\sqrt{Rt_s}$.
If the shell is not stiffened, the maximum stress occurs at the horn of the saddle. This stress is not be to added to the internal pressure-stress.
In a stiffened shell the maximum ring-compression is at the bottom of shell. Use stiffener ring if the circumferential bending stress exceeds the maximum allowable stress.

STRESSES IN LARGE HORIZONTAL VESSELS SUPPORTED BY TWO SADDLES

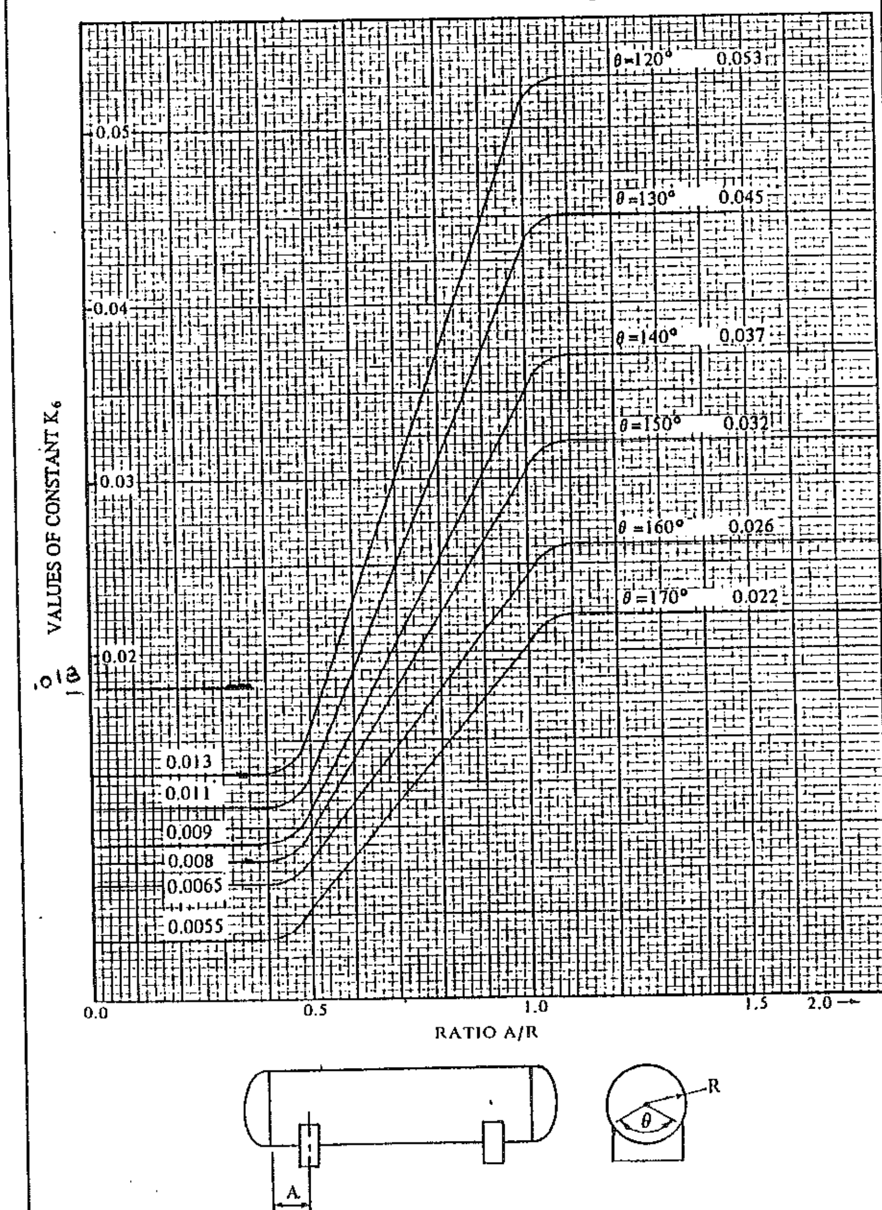
VALUES OF CONSTANT K
(Interpolate for Intermediate Values)

*K_1 = 3.14 if the shell is stiffened by ring or head (A < R/2)

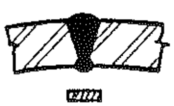
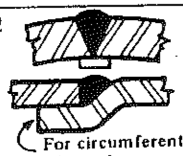
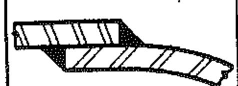
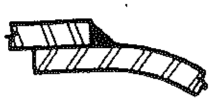
CONTACT ANGLE θ	K_1*	K_2	K_3	K_4	K_5	K_6	K_7	K_8
120	0.335	1.171		0.880	0.401		0.760	0.603
122	0.345	1.139		0.846	0.393		0.753	0.618
124	0.355	1.108		0.813	0.385		0.746	0.634
126	0.366	1.078		0.781	0.377		0.739	0.651
128	0.376	1.050		0.751	0.369		0.732	0.669
130	0.387	1.022		0.722	0.362		0.726	0.689
132	0.398	0.996		0.694	0.355		0.720	0.705
134	0.409	0.971		0.667	0.347		0.714	0.722
136	0.420	0.946		0.641	0.340		0.708	0.740
138	0.432	0.923		0.616	0.334		0.702	0.759
140	0.443	0.900	0.319	0.592	0.327		0.697	0.780
142	0.455	0.879	For	0.569	0.320	See	0.692	0.796
144	0.467	0.858	Any	0.547	0.314	chart	0.687	0.813
146	0.480	0.837	Con-	0.526	0.308	on	0.682	0.831
148	0.492	0.818	Tact	0.505	0.301	facing	0.678	0.853
150	0.505	0.799	Angles	0.485	0.295	page	0.673	0.876
152	0.518	0.781	θ	0.466	0.289		0.669	0.894
154	0.531	0.763		0.448	0.283		0.665	0.913
156	0.544	0.746		0.430	0.278		0.661	0.933
158	0.557	0.729		0.413	0.272		0.657	0.954
160	0.571	0.713		0.396	0.266		0.654	0.976
162	0.585	0.698		0.380	0.261		0.650	0.994
164	0.599	0.683		0.365	0.256		0.647	1.013
166	0.613	0.668		0.350	0.250		0.643	1.033
168	0.627	0.654		0.336	0.245		0.640	1.054
170	0.642	0.640		0.322	0.240		0.637	1.079
172	0.657	0.627		0.309	0.235		0.635	1.097
174	0.672	0.614		0.296	0.230		0.632	1.116
176	0.687	0.601		0.283	0.225		0.629	1.137
178	0.702	0.589		0.271	0.220		0.627	1.158
180	0.718	0.577		0.260	0.216		0.624	1.183

STRESSES IN LARGE HORIZONTAL VESSELS SUPPORTED BY TWO SADDLES

VALUES OF CONSTANT K_6



WELDED JOINTS

TYPES CODE UW-12		JOINT EFFICIENCY, E When the Joint: a. Fully Radio-graphed	b. Spot Examined	c. Not Examined
1 	Butt joints as attained by double-welding or by other means which will obtain the same quality of deposited weld metal on the inside and outside weld surface. Backing strip if used shall be removed after completion of weld.	1.00	0.85	0.70
2  For circumferential joint only	Single-welded butt joint with backing strip which remains in place after welding	0.90	0.80	0.65
3 	Single-welded butt joint without use of backing strip	–	–	0.60
4 	Double-full fillet lap joint	–	–	0.55
5 	Single-full fillet lap joint with plug welds	–	–	0.50
6 	Single full fillet lap joint without plug welds	–	–	0.45

WELDED JOINTS

LIMITATIONS IN APPLYING VARIES WELD TYPES

FOR TYPE 1
NONE

FOR TYPE 2 NONE
Except butt weld with one plate offset - for circumferential joints only.

FOR TYPE 3
Circumferential joints only, not over 5/8 in. thick and not over 24 in. outside diameter.

FOR TYPE 4
Longitudinal joints not over 3/8 in. thick. Circumferential joints not over 5/8 in. thick.

FOR TYPE 5
(a) Circumferential joints* for attachment of heads not over 24 in. outside diameter to shells not over 1/2 in. thick.
(b) Circumferential joints for the attachment to shells of jackets not over 5/8 in. in nominal thickness where the distance from the center of the plug weld to the edge of the plate is not less than 1-1/2 times the diameter of the hole for the plug.
*Joints attaching hemispherical heads to shells are excluded.

FOR TYPE 6
(a) For the attachment of heads convex to pressure to shells not over 5/8 in. required thickness, only with use of fillet weld on inside of shell; or (b) for attachment of heads having pressure on either side, to shells not over 24 in. inside diameter and not over 1/4 in. required thickness with fillet weld on outside of head flange only.

NOTES

1. In this table are shown the types of welded joints which are permitted by the code in arc and gas welding processes.
2. The shape of the edges to be joined by butt-weld shall be such as to permit complete fusion and penetration.
3. Butt joints shall be free from undercuts, overlaps and abrupt ridges and valleys. To assure that the weld-grooves are completely filled, weld metal may be built up as reinforcement. The thickness of the reinforcement shall not exceed the following thicknesses.

Plate thickness in.	Maximum reinf. in.
up to 1/2 incl.	3/32
over 1/2 to 1 incl.	1/8
over 1	3/16

4. Before welding the second side of a double welded butt joint, the impurities of the first side welding shall be removed by chipping, grinding or melting out to secure sound metal for complete penetration and fusion. For submerged arc welding, chipping out a groove in the crater is recommended.
5. The maximum allowable joint efficiencies given in this table are to be used in calculations of the loadings, when the joints made by arc or gas welding processes.
6. The code restricts the use of welded joints to certain types for vessels in the following services:
   a. When vessels are to contain lethal substances
   b. When vessels are to operate below -20F
   c. Unfired steam boilers with design pressures exceeding 50 psi.
   d. Pressure vessels subject to direct firing (Code UW-2).
7. The following butt welded joints shall be examined radiographically for their full length.
   a. Joints in vessels used to contain lethal substances.
   b. Joints in which the thinner of the plate at the welded joint exceeds 1-1/2 in. or exceeds the lesser thickness prescribed in UCS-57 (e.g. for P-1 materials 1-1/4 in.)
   c. Joints in unfired steam boilers, the design pressure of which exceeds 50 psi.
   d. Joints in nozzles, communicating chambers, etc. in vessel or vessel section that is required to be radiographed under a, b, and c. [See UW-11 (4)].
8. If the vessel is spot radiographed the seamless vessel sections and heads joined with butt welds shall be designed using a stress value equal to 85 percent of the allowable stress value prescribed for the material. UW-12 (b). See example on the following page.
9. If the vessel radiographically is not examined, and the joint efficiencies given in column (c) are used in all other than welded joint calculation, a stress value equal to 80 percent allowed for the material shall be used. UW-12 (c). See example on the following page.

VOLUME OF SHELL & HEADS

I.D. of Vessel in.	ASME F & D. HEAD*				HEMIS. HEAD*			
	Cu.Ft.	Gal.	Bbl.	Wt. of Water lb.	Cu.Ft.	Gal.	Bbl.	Wt. of Water lb.
12	0.08	0.58	0.01	4.83	0.26	1.96	0.05	16.34
14	0.12	0.94	0.02	7.83	0.42	3.11	0.07	25.95
16	0.19	1.45	0.03	12.08	0.62	4.64	0.11	38.74
18	0.27	2.04	0.05	17.00	0.88	6.61	0.16	55.16
20	0.37	2.80	0.07	28.33	1.21	9.07	0.22	75.66
22	0.50	3.78	0.09	31.49	1.61	12.07	0.29	100.7
24	0.65	4.86	0.12	40.49	2.09	15.67	0.37	130.7
26	0.82	6.14	0.15	51.15	2.66	19.92	0.47	166.2
28	1.10	8.21	0.20	68.40	3.33	24.88	0.59	207.6
30	1.30	9.70	0.23	80.81	4.09	30.60	0.73	255.4
32	1.64	12.30	0.29	102.5	4.96	37.14	0.88	309.9
34	1.88	14.10	0.34	117.5	5.95	44.54	1.06	371.7
36	2.15	16.10	0.38	134.1	7.07	52.88	1.26	441.2
38	2.75	20.60	0.49	171.6	8.31	62.19	1.48	519.0
40	3.07	23.00	0.55	191.6	9.70	72.53	1.73	605.3
42	3.68	27.50	0.65	229.1	11.22	83.97	2.00	700.7
48	5.12	38.30	0.91	319.1	16.76	125.3	2.98	1046
54	7.30	54.60	1.30	454.9	23.86	178.5	4.25	1489
60	10.08	75.40	1.80	628.2	32.73	244.8	5.83	2043
66	13.54	101	2.41	843.9	43.56	325.8	7.76	2719
72	17.65	132	3.14	1100	56.55	423.0	10.07	3530
78	22.32	167	3.98	1391	71.90	537.8	12.80	4488
84	28.47	213	5.07	1775	89.80	671.7	16.00	5606
90	35.56	266	6.33	2216	110.4	826.2	19.67	6895
96	42.51	318	7.57	2649	134.0	1003	23.87	8368
102	52.14	390	9.29	3249	160.8	1203	28.63	10037
108	60.96	456	10.86	3799	190.9	1428	34.00	11914
114	73.66	551	13.12	4590	224.5	1679	39.98	14012
120	84.35	631	15.02	5257	261.8	1958	46.63	16343
126	97.32	728	17.33	6065	303.1	2267	53.98	18919
$\boxed{132}$	$\boxed{108.7}$	813	19.36	6773	348.5	2607	62.06	21752
138	127.0	950	22.62	7915	398.2	2978	70.91	24856
144	147.9	1106	26.33	9214	452.4	3384	80.57	28241

*Volume within the straight flange is not included

[19]

AREA OF SURFACES
(In Square Feet)

Outside Diameter of Vessel D inches	Cylindrical Shell per Lineal Foot (π x D)	2:1 Ellipsoidal Head (1.09 x D^2)	ASME Flanged and Dished Head (0.918 x D^2)	Hemis-pherical Head (1.5708 x D^2)	Flat Head (0.7854 x D^2)
12	3.14	1.09	0.92	1.57	0.79
14	3.66	1.48	1.25	2.14	1.07
16	4.19	1.94	1.64	2.79	1.40
18	4.71	2.45	2.07	3.53	1.77
20	5.23	3.02	2.56	4.36	2.18
22	5.76	3.66	3.10	5.28	2.64
24	6.28	4.36	3.68	6.28	3.14
26	6.81	5.12	4.32	7.08	3.69
28	7.32	5.92	5.00	8.55	4.28
30	7.85	6.81	5.76	9.82	4.91
32	8.37	7.76	6.53	11.17	5.58
34	8.90	8.75	7.39	12.11	6.31
36	9.43	9.82	8.29	14.14	7.07
38	9.94	10.93	9.21	15.75	7.88
40	10.47	12.11	10.20	17.44	8.72
42	11.00	13.35	11.25	19.23	9.62
48	12.57	17.47	14.70	25.13	12.57
54	14.14	22.09	18.60	31.81	15.90
60	15.71	27.30	23.60	39.27	19.64
66	17.28	33.10	27.80	47.52	23.76
72	18.85	39.20	$\boxed{33.00}$	56.55	28.27
78	20.42	46.00	38.85	66.37	33.18
84	21.99	53.40	45.00	76.97	38.49
90	23.56	61.20	51.60	88.37	44.16
96	25.20	69.80	58.90	100.54	50.27
102	26.70	78.80	66.25	113.43	56.25
108	28.27	88.25	74.35	127.25	63.62
114	29.85	98.25	83.00	141.78	70.88
120	31.50	109.00	92.00	157.08	78.87
126	32.99	120.11	100.85	173.20	86.59
132	34.56	132.00	111.50	190.09	95.03
138	36.20	144.00	121.50	207.76	102.00
144	37.70	157.00	132.20	226.22	113.50

Structural Assessment of a Hazardous Waste Storage Tank
for Hukill Chemical Company

Spent Acid System - Spent Acid Tank
Exhibit D-9

Extrapolation of Values for Constant K_8
Reference [19-pg 76]

	θ	K_8	Difference	Increment
Extrapolated Values	90°	0.382		
			0.067	
	100°	0.449		0.007
			0.074	
	110°	0.523		0.006
			0.080	
	120°	0.603		0.006
			0.086	
Table Values	130°	0.689		0.005
			0.091	
	140°	0.780		0.005
			0.096	
	150°	0.876		0.004
			0.100	
	160°	0.976		0.003
			0.103	
	170°	1.079		0.001
			0.104	
	180°	1.183		

Structural Assessment of a Hazardous Waste Storage Tank
for Hukill Chemical Company

Spent Acid System - Spent Acid Tank
Exhibit D-9

Extrapolation for Values for Constant K_7
Reference [19-pg 76]

	θ	K_7	Difference	Increment
Extrapolated	90°	0.899		
Values			0.053	
	100°	0.846		0.007
			0.046	
	110°	0.800		0.006
			0.040	
Table	120°	0.760		0.006
Values			0.034	
	130°	0.726		0.005
			0.029	
	140°	0.697		0.005
			0.024	
	150°	0.673		0.005
			0.019	
	160°	0.654		0.002
			0.017	
	170°	0.637		0.004
			0.013	
	180°	0.624		

EDP/TRIGGS
Consultants, Inc.

July 7, 1988

Hukill Chemical Corporation
7013 Krick Road
Bedford, Ohio

Atten: Mr. Ed Price

Hukill Chemical Corporation
Tank Farm Expansion
Bedford, Ohio
EDP/TRIGGS #88166

Gentlemen

We have completed subsurface exploration work for the proposed Tank Farm to be added to Hukill Chemical's existing facility in Bedford, Ohio. Three copies of our "Report of Subsurface Exploration are enclosed for your use and distribution.

We have recommended that the propose tank support/containment slab be supported by conventional strip footings. The footings are to be excavated through any fill to bear on undisturbed soil.

We are ready to provide the necessary plan and specification review and construction observation and testing services as described in this report. These services are important to this project's successful construction and performance.

If you have any questions about the findings or recommendations of this report, or require additional geotechnical services for this project, please call us.

Very truly yours

EDP/TRIGGS Consultants, Inc.

John E. Dingeldein

John E. Dingeldein, P.E.
Project Engineer

Alan J. Esser

Alan J. Esser, P.E.
Reviewing Engineer

1. Scope of Report

This report presents the results of a subsurface exploration for a tank farm addition to the Hukill Chemical Corporation facility in Bedford, Ohio. Subsurface conditions were identified by a field exploration program consisting of 3 borings in the tank foundation area supplemented by borings made during previous explorations at the site. Selected soil samples were tested in the laboratory, and field and laboratory tests were interpreted, resulting in recommendations for foundation design.

2. Proposed Project

From information provided by Mr. Ed Price, we understand that a reinforced concrete slab with above grade concrete retaining walls is proposed for construction. The slab will measure approximately 35 feet by 90 feet in plan dimension. It will support up to 16 steel tanks. The above grade retaining walls are designed to help contain leaks or spills. The slab will be located just north of the existing tank farm.

The preceding information represents our understanding of the proposed project, and is an important part of our engineering interpretation of the site explored. If this understanding is not correct or if project conditions change, we must review this report relative to our recommendations.

3. Site Conditions

The site is located on the north side of Hukill Chemical Corporation's existing facility at 7013 Krick Road in Bedford, Ohio. The proposed foundation slab will be located adjacent to the north side of the existing farm's earth containment dike. A gravel road passes through the area. A small grass-covered field is located north of the road. Site topography is relatively level in the construction area.

The site is located in a area know for glacial deposits and shallow bedrock. Residual soils are often encountered below the glacial deposits and above bedrock. Existing ground water monitoring wells are located around the site.

4. Field Exploration

Subsurface conditions were studied by an exploration program consisting of three new Standard Penetration Test borings supplemented by data from six borings made in 1982. Approximate test locations are shown on the enclosed Boring Location Plans.

Borings were drilled to depths of 15 feet during the current exploration. Due to the near level surface grades on the site, boring elevations were not determined.

The borings were drilled in accordance with ASTM standards. A two inch O.D. split-spoon sampler was driven into the soil using a 140 lb. hammer dropping 30 inches. The number of blows required to drive the sampler was recorded for each of three, six inch penetration intervals at each sample location.

Three inch O.D. thin-wall Shelby tube samples were hydraulically pressed at the following locations and depths:

B-1; 3.5 to 5.5 ft.
B-2; 6.5 to 8.5 ft.

Groundwater was not encountered at the time of the exploration.

The results of this field exploration are presented on the enclosed boring logs.

5. Laboratory Testing

Samples were delivered to our laboratory, where they were examined and classified by a geotechnical engineer following ASTM Standards. Selected soil and bedrock samples were then tested according to the following schedule:

TEST	SAMPLES
Water Content	A total of 11 split-spoon samples from selected locations
Unconfined Compression, with Unit Weight and Water Content	B-1; 4.9 to 5.4 ft. B-2; 7.0 to 7.3 ft.

Water content tests are indicators of soil consistency, strength, and compressibility. Unconfined compression tests provide data concerning soil shear strength and bearing capacity. Water contents, unconfined compressive strengths, and dry unit weights are listed on the boring logs. Stress-strain curves from unconfined compression tests are presented on enclosed data sheets

6. Subsurface Profile

Based upon the subsurface and laboratory data obtained during the exploration, the soil profile for the tank slab area can be generalized as fill overlying topsoil, glacial till and residual deposits, and shale bedrock.

Fill was encountered at all of the boring locations within the proposed tank farm addition area. Its depth ranged from approximately 1-1/2 feet to 6 feet. The fill material was variable in composition.

[21]3

Deposits of glacial and residual soils were encountered beneath the fill. These soils were predominantly clays having varying amounts of sand and gravel size pieces. The clay's consistency ranged from very stiff to hard.

Shale bedrock was encountered in all of the borings at depths which ranged from approximately 7-1/2 to 12-1/2 feet. Rock hardness ranged from very soft to soft.

Groundwater was not encountered in the borings at the time of our exploration. Groundwater levels, however can be measured using the existing monitoring wells at the site.

Subsurface conditions at other times and locations on the site may differ from those found at our test locations. If different conditions are encountered during construction, it is necessary that you contact us so that our recommendations can be reviewed.

7. Engineering Interpretation and Recommendations

We have interpreted the subsurface and laboratory data relative to the proposed construction. Several foundation alternatives were reviewed with Mr. Price prior to completing this report. The recommendation presented, in our opinion, represents the best approach based upon the geotechnical and environmental concerns of the project.

A. Foundations

As we discussed, there is fill placed over the proposed tank concrete slab area. This fill is quite variable in consistency and composition and is not suitable for foundation support. The slab should either be supported structurally, or may be constructed on new engineered fill. The engineered fill solution has been ruled out due to the amount of soil which would have to be removed and disposed of.

Several foundation systems for supporting the 35 by 90 ft slab were considered. Due to environmental considerations, a shallow strip footing system was considered most practical for supporting the slab. Strip footings should bear on very stiff to hard brown lean clay below any fill. The borings indicate that the bearing soil may be encountered at depths of 1-1/2 to 6 feet below existing site grades. Footing depths should be no shallower than 3.5 feet below grade for protection against frost related heave. Footings may be proportioned for a maximum net allowable bearing pressure of 4,000 psf. The concrete slab should be designed as an unsupported slab with all loads being transferred to the footings. The footing trenches should be cleaned of all loose cuttings and free of water prior to placing concrete. The top of the slab could be set at an elevation which would allow the spoil from the footing excavations to be used as compacted fill beneath the slab.

B. Construction Observation and Testing

A soils technician working under the direct supervision of the project geotechnical engineer should be present during foundation construction, to verify compliance with the recommendations contained in this report.

The technician's duties would include, but not be limited to:

a. Identifying proper quality bearing materials.

b. Observing the foundation bearing surface and bearing depth, and verifying that excess water, mud, and loose soil has been removed.

c. Checking the placement of reinforcement.

d. Sampling and testing concrete for compliance with the project specifications.

C. Remarks

The recommendations and observations contained in this report are professional estimates based upon data which are assumed to be representative of the site studied. Variations in subsurface conditions may occur below or between the locations tested. This report was developed in accordance with currently accepted engineering practices at this time and location.

8. <u>Signatures</u>

John E. Dingeldein, P.E.
Project Engineer

Alan J. Esser, P.E.
Reviewing Engineer

Table 6-51B. Volume of Cylinders, 10 to 98 Ft. Diameter*

Diam., ft.	in.	Gal./ft.	Diam., ft.	in.	Gal./ft.	Diam., ft.	Gal./ft.	Diam., ft.	Gal./ft.
10	0	588	17	6	1,799	30	5,288	55	17,770
10	3	617	18	0	1,904	31	5,650	56	18,420
10	6	648	18	6	2,011	32	6,020	57	19,090
10	9	679	19	0	2,121	33	6,400	58	19,760
11	0	711	19	6	2,234	34	6,790	59	20,450
11	3	744	20	0	2,350	35	7,200	60	21,150
11	6	777	20	6	2,469	36	7,610	62	22,580
11	9	811	21	0	2,591	37	8,040	64	24,060
12	0	846	21	6	2,716	38	8,480	66	25,590
12	3	882	22	0	2,844	39	8,940	68	27,170
12	6	918	22	6	2,974	40	9,400	70	28,790
12	9	955	23	0	3,108	41	9,880	72	30,460
13	0	993	23	6	3,244	42	10,360	74	32,170
13	3	1,031	24	0	3,384	43	10,860	76	33,930
13	6	1,071	24	6	3,526	44	11,370	78	35,740
13	9	1,111	25	0	3,672	45	11,900	80	37,600
14	0	1,152	25	6	3,820	46	12,430	82	39,500
14	3	1,193	26	0	3,972	47	12,980	84	41,450
14	6	1,235	26	6	4,126	48	13,540	86	43,450
14	9	1,278	27	0	4,283	49	14,110	88	45,500
15	0	1,322	27	6	4,443	50	14,690	90	47,590
15	6	1,411	28	0	4,606	51	15,280	92	49,730
16	0	1,504	28	6	4,772	52	15,890	94	51,910
16	6	1,599	29	0	4,941	53	16,500	96	54,140
17	0	1,698	29	6	5,113	54	17,130	98	56,420

*Gal./ft. = $5.875D^2$, where D = diameter, ft.

Table 6-52. Volume of Partially Filled Horizontal Cylinders

H/D	Fraction of volume	H/D	Fraction of volume	H/D	Fraction of volume	H/D	Fraction of volume
0.01	0.00169	0.26	0.20660	0.51	0.51273	0.76	0.81545
.02	.00477	.27	.21784	.52	.52546	.77	.82625
.03	.00874	.28	.22921	.53	.53818	.78	.83688
.04	.01342	.29	.24070	.54	.55088	.79	.84734
.05	.01869	.30	.25231	.55	.56356	.80	.85762
.06	.02450	.31	.26348	.56	.57621	.81	.86771
.07	.03077	.32	.27587	.57	.58884	.82	.87760
.08	.03748	.33	.28779	.58	.60142	.83	.88727
.09	.04458	.34	.29981	.59	.61397	.84	.89673
.10	.05204	.35	.31192	.60	.62647	.85	.90594
.11	.05985	.36	.32410	.61	.63892	.86	.91491
.12	.06797	.37	.33636	.62	.65131	.87	.92361
.13	.07639	.38	.34869	.63	.66364	.88	.93203
.14	.08509	.39	.36108	.64	.67590	.89	.94015
.15	.09406	.40	.37353	.65	.68808	.90	.94796
.16	.10327	.41	.38603	.66	.70019	.91	.95542
.17	.11273	.42	.39858	.67	.71221	.92	.96252
.18	.12240	.43	.41116	.68	.72413	.93	.96923
.19	.13229	.44	.42379	.69	.73652	.94	.97550
.20	.14238	.45	.43644	.70	.74769	.95	.98131
.21	.15266	.46	.44912	.71	.75930	.96	.98658
.22	.16312	.47	.46182	.72	.77079	.97	.99126
.23	.17375	.48	.47454	.73	.78216	.98	.99523
.24	.18455	.49	.48727	.74	.79340	.99	.99831
.25	.19550	.50	.50000	.75	.80450	1.00	1.00000

numerically to $\alpha/57.30$. Table 6-52 gives liquid volume, for a partially filled horizontal cylinder, as a fraction of the total volume, for the dimensionless ratio H/D or $H/2R$.

The volumes of heads must be calculated separately and added to the volume of the cylindrical portion of the tank. The four types of heads most frequently used are the standard dished head,* torispherical or A.S.M.E. head, ellipsoidal head, and hemispherical head. Dimensions and volumes for all four of these types are given in "Lukens Spun Heads," Lukens Steel Co., Coatesville, Pa. Approximate volumes can also be calculated by the formulas in Table 6-53. Consistent units must be used in these formulas. It should be remembered that volumes are given for one head but that usually two heads are involved.

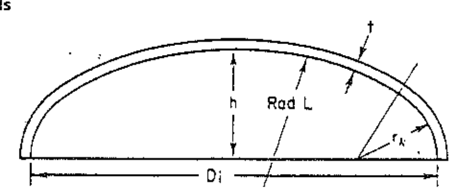
A partially filled horizontal tank requires the determination of the partial volume of the heads. The Lukens catalog gives approximate volumes for partially filled (axis horizontal) standard, A.S.M.E., and ellipsoidal heads. A formula for partially filled heads, by Doolittle [*Ind. Eng. Chem.* 21, 322–323 (1928)], is

$$V = 0.00093H^2(3R - H) \qquad (6\text{-}46)$$

where V = volume, gal.; R = radius, in.; and H = depth of liquid, in. Doolittle made some simplifying assumptions which affect the volume given by the equation, but the equation is satisfactory for determining the volume as a fraction of the entire head. This

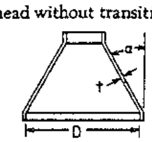
*The standard dished head does not comply with the A.S.M.E. Pressure Vessel Code.

Table 6-53. Volumes of Heads
(Use consistent units)



Type of head	Knuckle radius r_k	h	L	Volume	% Error	Remarks
Standard dished	Approx. $3t$	......	Approx. D_i	Approx. $0.050D_i^3 + 1.65tD_i^2$	±10	h varies with t
Torispherical or A.S.M.E.	$0.06L$	......	D_i	$\boxed{0.0809D_i^3}$	±0.1	r_k must be the larger of $0.06L$ and $3t$
Torispherical or A.S.M.E.	$3t$	......	D_i	Approx. $0.513hD_i^2$	±8	
Ellipsoidal	......	......	......	$\pi D_i^2h/6$	0	
Ellipsoidal	......	$D_i/4$	......	$\pi D_i^3/24$	0	Standard proportions
Hemispherical	......	$D_i/2$	$D_i/2$	$\pi D_i^3/12$	0	
Conical	......	......	......	$\pi h(D_i^2 + D_id + d^2)/12$	0	Truncated cone h = height d = diameter at small end

Table 6-56. Vessel Design Formulas for Internal Pressure

Description	Formulas		Notes
Cylindrical shell	$t = \dfrac{PR}{SE - 0.6P}$	$P = \dfrac{SEt}{R + 0.6t}$	Circumferential stress (longitudinal joints) when t does not exceed $0.5R$ or P does not exceed $0.385SE$.
Spherical shell	$t = \dfrac{PR}{2SE - 0.2P}$	$P = \dfrac{2SEt}{R + 0.2t}$	When t does not exceed $0.356R$ or P does not exceed $0.665SE$.
Hemispherical head	$t = \dfrac{PL}{2SE - 0.2P}$	$P = \dfrac{2SEt}{L + 0.2t}$	When t does not exceed $0.356L$ or P does not exceed $0.665SE$. L = inside radius.
Ellipsoidal head (semiellipsoidal)	$t = \dfrac{PD}{2SE - 0.2P}$	$P = \dfrac{2SEt}{D + 0.2t}$	For semiellipsoidal heads in which $h = D/4$.
	$t = \dfrac{PDK}{2SE - 0.2P}$	$P = \dfrac{SEt}{DK + 0.2t}$	For values of D/h from 2 to 6. $K = \frac{1}{6} \times [2 + (D/2h)^2]$.
Torispherical (spherically dished) head	$\boxed{t = \dfrac{0.885PL}{SE - 0.1P}}$	$P = \dfrac{SEt}{0.885L + 0.1t}$	For standard A.S.M.E. heads in which min. knuckle radius = 6% of inside crown radius but is not less than $3t$. L must not exceed $D + 2t$.
	$t = \dfrac{PLM}{2SE - 0.2P}$	$P = \dfrac{2SEt}{LM + 0.2t}$	For values of L/r from 1 to $16\frac{2}{3}$. $M = \frac{1}{4}(3 + \sqrt{L/r})$. r must be at least $3t$ and $0.06 \times (D + 2t)$. L must not exceed $D + 2t$.
Conical head without transition knuckle 	$t = \dfrac{PD}{2 \cos \alpha (SE - 0.6P)}$	$P = \dfrac{2SEt \cos \alpha}{D + 1.2t \cos \alpha}$	A reinforcing ring may be required. See Code paragraphs UA5 (b) and (c). Applicable for $\alpha \leq 30°$.

Nomenclature:
t = shell or head thickness, in.
P = pressure, lb./sq. in.
S = allowable stress, lb./sq. in.
E = joint efficiency, dimensionless
R = inside radius, in.
D = inside diameter of head skirt, or inside length of major axis of an ellipsoidal head, in.
h = inside depth of an ellipsoidal head, in.
r = inside knuckle radius of a torispherical head, in.
L = inside radius of hemispherical head or inside crown radius of a torispherical head, in.

(Appendix). There are also rules for openings in flat heads and for closely spaced openings.

Reinforcement may be added by welding rings of plate or bar around the opening. Sometimes a heavy ring may be inserted in an opening in the shell, as shown in Fig. 6-135*a*. Although this is accepted by the Code, it is not favored. Another type which is used, particularly in high-pressure vessels, is a forged nozzle inserted as shown in Fig. 6-135*b*. This is an excellent design and the weld can be radiographed.

The Code does not limit the size or shape of openings. It does, however, have special rules and recommendations for openings of certain shapes and sizes.

Flange design procedures are specified by the Code for joints that are circular in shape and have the gasket located inside the bolt circle. In such flanges there is a moment arm between the circle on which the bolt force W is applied and the circles on which the opposing gasket force H_G and hydraulic thrust H_D are applied. This principle is illustrated in a simplified way in Fig. 6-136*a*. Actual flange calculations may involve additional forces.

Applying the forces H_G and H_D with their corresponding moment arms h_G and h_D produces bending moments which try to turn the flange inside out. If the flange does not have sufficient strength and rigidity to resist these moments, its cross section will rotate enough to open a gap at the gasket and permit leakage. This is illustrated in an exaggerated view in Fig. 6-136*b*. Appendix II of the Code contains detailed procedures, gasket data, and curves for calculating flange loads, moments, and stresses.

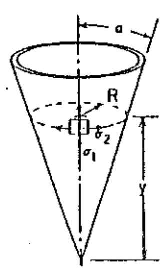
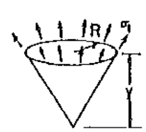
The Code classifies flanges in two basic types—integral and loose. The **integral-type flange** is constructed in such a way that it obtains some strength from its hub and from the nozzle or vessel wall to which it is attached. **Loose-type flanges** are attached in such a manner that they cannot safely be assumed to obtain strength in this way. They must resist all of the moment internally. Section VIII, Division 1, has a third category, called **optional-type flanges.** Examples of all three types of flanges are shown in Fig. 6-137. (See Code Par. UA-48.)

Code flange design, as specified in Appendix II, involves the calculation of two types of loads, minimum required bolt load for gasket seating, and minimum required bolt load for the operating conditions. When a joint is initially put together, it is necessary to apply sufficient force on the gasket to make it conform to the surface of the flange. Code Table UA-49.1 gives suggested values of **minimum design seating stress** which is necessary to "yield" each particular type of gasket and make it conform to the flange surface. These stress values vary from 0 for rubber to 26,000 lb./sq. in. for stainless steel. The **minimum required bolt load for gasket seating** is determined by applying this stress to a prescribed fraction of the gasket area (calculated by formula). The flange and bolting are designed to carry this load (as well as the resulting moment), using the stresses allowed in the materials at atmospheric temperature. The entire gasket area is not used in calculating seating load, because the deflection of the flange causes it to bear most heavily at the outer edge of the gasket.

When a joint must withstand internal pressure, the Code assumes that leakage will not occur if the flange bears against the gasket with a pressure that is a certain multiple of the internal pressure in the vessel. This multiple is known as the **gasket factor.** Code Table UA-49.1 gives suggested values which vary from 0.5 for soft rubber to 2.0 for $\frac{1}{8}$-in.-thick compressed asbestos and to 6.5 for stainless steel. If internal pressure is 100 lb./sq. in. and gasket factor is 2.0, then the flange must exert a pressure of 200 lb./sq. in. against the gasket. Applying this pressure to a specified portion of the

TABLE 29 ***Formulas for membrane stresses and deformations in thin-walled pressure vessels***

NOTATION: P = axial load (pounds); p = unit load (pounds per linear inch); q and w = unit pressures (pounds per square inch); δ = density (pounds per cubic inch); σ_1 = meridional stress (pounds per square inch); σ_2 = circumferential, or hoop, stress (pounds per square inch); R_1 = radius of curvature of a meridian, a principal radius of curvature of the shell surface (inches); R_2 = length of the normal between the point on the shell and the axis of rotation, the second principal radius of curvature (inches); R = radius of curvature of a circumference (inches); ΔR = radial displacement of a circumference (inches); Δy = change in the height dimension y (inches); ψ = rotation of a meridian, positive when ΔR increases with y (radians); E = modulus of elasticity (pounds per square inch); and ν = Poisson's ratio

Case no., form of vessel	Manner of loading	Formulas
2. Cone  $\frac{R_2}{t} > 10$	2a. Uniform internal or external pressure, q lb/in^2; tangential edge support 	$\sigma_1 = \frac{qR}{2t\cos\alpha}$ $\sigma_2 = \frac{qR}{t\cos\alpha}$ $\Delta R = \frac{qR^2}{Et\cos\alpha}\left(1 - \frac{\nu}{2}\right)$ $\Delta y = \frac{qR^2}{4Et\sin\alpha}(1 - 2\nu - 3\tan^2\alpha)$ $\psi = \frac{3qR\tan\alpha}{2Et\cos\alpha}$

Attachment C

ATTACHMENT C

CONTAINMENT COATING INFORMATION

INSTRUCTION MANUAL

PRINCO MODEL L3502

NULL-KOTE

PROB-A-LARM

PRINCO

1020 INDUSTRIAL HWY.
SOUTHAMPTON, PA. 18966

MODEL L3502 CONTROL WITH PROBE

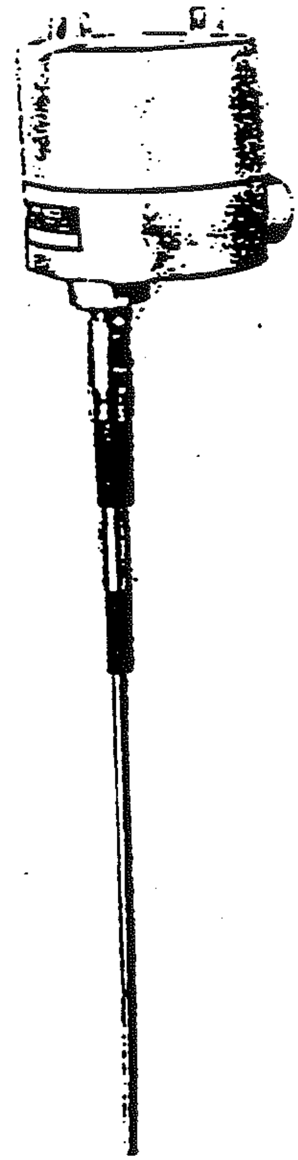


ILLUSTRATION OF EQUIPMENT

SECTION 1

DESCRIPTION

Princo's Model L3502 Point Level Control is truly universal in its ability to work with practically all process control type liquids and materials. Its unique circuit design forms the basis for Princo's Null-Kote™ system, which ignores build-up, even conductive coating on the sensing probe.

Operating on RF (Radio Frequency) Impedance sensing principle, the L3502 will detect the presence (high level) or absence (low level) of virtually any material or liquid in any type of storage bin or tank. Likewise, it may be made Fail-Safe in either high or low mode. Because of its excellent stability and wide range sensitivity, the L3502 will operate in conjunction with process materials which range from low dielectric products such as refined oils to conductive slurries.

The Model L852 sensing probe is the standard probe (others optional) employed by the L3502. Its sensing and guard elements are constructed of 316 stainless steel. Insulating sections are made of molded epoxy resin. This probe is suited to a wide range of applications, including many having corrosive process materials.

SECTION 2

SPECIFICATIONS

TYPE

Point type (on/off), high frequency (RF), impedance sensing, all solid state level controller.

SENSITIVITY

Senses capacitance as low as 0.15pF and material with dielectric constant as low as 1.5. Sensitivity may be decreased to approximately 1000pF.

AMBIENT TEMPERATURE RANGE

-40 to 150°F (-40 to 66°C)

TEMPERATURE STABILITY

Temperature coefficient is 0.0025pF/°F (0.0045pF/°C).

RELAY CONTACTS

Two sets of form C contacts, rated as 10 amperes, 115V AC or 26V DC, resistive load.

DELAY TIME AND DELAY MODE OPTIONS

Standard delay is 0 to 30 seconds, standard mode is delayed turn-on and delayed turn-off. Optional delays are 0 to 10 or 0 to 60 seconds. Optional modes are delayed turn-on with instant off, or delayed turn-off with instant on.

POWER REQUIREMENTS

95 to 125V AC, 50 to 60 Hz, 5 watts, or 24Vdc ±10%, or 12Vdc ±10%, 5 watts. (Select applicable power source).

ELECTRONIC HOUSING

Heavy duty cast aluminum. Explosion proof Class 1, groups C & D, Class II, Groups E, F & G. Weatherproof, FM Approved.

Attachment D

ATTACHMENT D

HIGH LEVEL INSTRUMENT SPECS.

SILOXIRANE C2033

PROTECTIVE LINING FOR SULPHURIC ACID SERVICE AND CORROSIVE ENVIRONMENTS REQUIRING AMBIENT CURE

DESCRIPTION

Siloxirane® C2033 is a two component polymer system. It is an organic-inorganic thermoset polymer having an oxygen-to-carbon linkage with a very dense, highly cross-linked molecular structure. The absence of problematic hydroxyl and ester groups makes Siloxirane impervious to a wide range of corrosive and erosive materials. Excellent for sulphuric acid service from 1% to 98%.

APPLICATIONS

Siloxirane® may be used on steel substrate that has been properly prepared, on alloys, glass, concrete, wood, plastics, etc.; it can be applied by spraying, trowelling or brushing. Although normally cured at 180-200°F, Siloxirane® C2033 can be cured at ambient temperatures (60°F and above). This makes it especially suitable for use on structural steel, concrete dikes, concrete acid and waste water pits, etc., where curing at elevated temperatures is difficult or impractical. It is capable of handling acids, alkalies and solvents.

SUMMARY OF BENEFITS

- Broad range of chemical resistance
- Steam cleanable
- Unique temperature span: -80°F to +200°F
- Non-absorbent
- Coeff. of expansion similar to that of stainless steel
- Maintains a tough, hard surface
- Easily patched by maintenance personnel
- Outstanding abrasion wear resistance
- Excellent adhesion, even with flexing
- Complies with FDA 21 CFR 177.2420

TYPICAL PROPERTIES

• Finish	Oyster White
• Weight per Gallon	11.0 lbs.
• V.O.C. Level	0.85 lbs. per gallon
• Lead Content	Zero
• Kit Size	3 Gallons C2001 Resin 35.2 Ounces C2033 Catalyst
• Activator	C2033 Catalyst
• Pot Life	1.5 hours at 80°F and 50% rel. hum.
• Viscosity	Reduce with MEK to 12-13 seconds with a Zahn #5
• Flash Point	53°F
• Solids by Volume	86.9%
• Solids by Weight	92.8%
• Chromate Content	Zero
• Theoretical Coverage	1360 sq. ft. per gal. at 1 mil DFT
• Recommended DFT	10-13 mils dry 12-14 mils wet (1 or 2 coat applic. - see directions)
• Shelf Life	One year minimum when stored at 50-90°F

ADVANCED
POLYMER SCIENCES, INC.

Avon, OH 44011
Phone 800-334-7193 Telex 985504 Fax 216-937-5046

SILOXIRANE C2033

PHYSICAL PROPERTIES

Tensile Strength (ASTM D638)	40°F	12,900 p.s.i.
	75°F	11,340 p.s.i.
Flexural Strength		18,650 p.s.i.
Flexural Modulus (ASTM D790)		0.816 k.s.i.
Water Absorbtion (ASTM D570)	(30 days in 88°C Water)	0.25%
Permeability - Vapor Transmission of Water at 90°C for 7 Days		0.0000 gm per sq. ft. per 7 days per inch thickness
Thermal Properties: Coeff. of Thermal Expansion -50°C to 150°C (ASTM D696)		19 (in/in/°C x 10^{-6})
Coeff. of Thermal Conductivity (ASTM D2214)		80×10^{-4} (cal/sec. cm². °C.cm)
Lap Shear Strength (Adhesion) (ASTM 1002)	-67°F	2,280 p.s.i.
	75°F	2,720 p.s.i.
	350°F	1,994 p.s.i.
	535°F	1,180 p.s.i.
Heat Deflection Temp. (ASTM D648)	264 p.s.i.	300°F
Tensile Modulus (ASTM D63F)	-40°F	0.69 m.s.i.
	75°F	0.89 m.s.i.
Elongation	-40°F	5.09%
	75°F	4.38%
Hardness		75-78 Barcol
Impact Resistance (ASTM D2794)		37 in/lbs
U.V. Light Resistance (ASTM G53)		40+ years

PRINCIPAL USES

- Water white sulfuric acid service. SILOXIRANE® C2033 offers protection to a wide range of equipment such as tanks, reactors,pumps, scrubbers, pipes, ducts, waste water pits, etc., in the following industries:

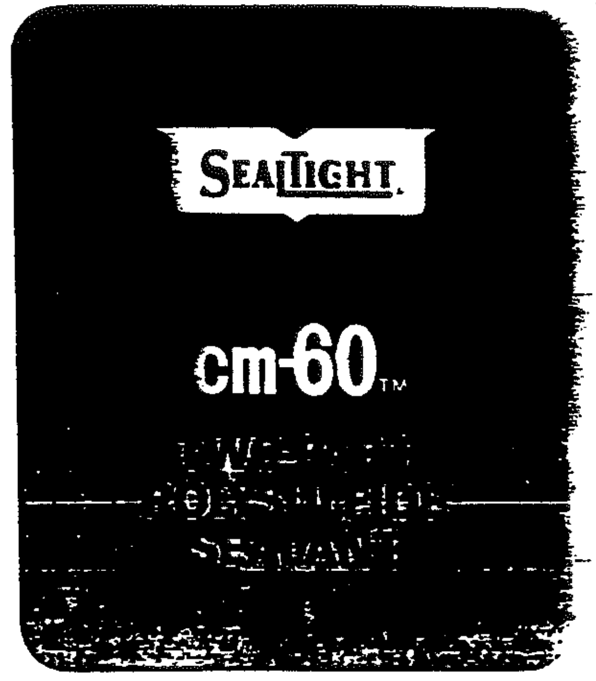
Chemical and Petrochemical Processing
Petroleum Refining
Mining and Smelting
Paper and Pulp
Hazardous Waste Disposal and Management
Transportation
Power Generation
Steel

CHEMICAL RESISTANCE:

Sulphuric acid to 98% at 200°F, most solvents including methanol, gasohol, distilled water, inorganic acids, dilute organic acids and alkalies. Ideal for corrosive vapor environments.

ADVANCED POLYMER SCIENCES, INC.

Avon, OH 44011
Phone 800-334-7193 Telex 985504 Fax 216-937-5046



GENERAL

SEALTIGHT CM-60™ TWO-PART POLYSULFIDE SEALANT is a gun-grade, two-component, non-sag joint sealant, composed of a Thiokal* polysulfide liquid polymer base. It is excellent for sealing joints between tilt-up and pre-cast panels, for sealing perimeter joints of window units and joints between curtain wall panels as well as glazing of metal and glass panels, flashings, coping joints, etc. Suitable for all vertical wall joints requiring a high performance sealant. Also ideal for the sealing, caulking and glazing of all kinds of pre-cast assemblies, expansion joints, window channels, doors, sills and ventilators as well as foundations, retaining walls, swimming pools, reservoirs, tunnels, locks, etc.

It cures within 24 hours to a permanent, flexible, rubber-like consistency with outstanding stretch. After complete cure, CM-60 will withstand ±12.5% joint movement. In addition, CM-60 withstands extremes of repeated joint expansion/contraction over a practical service temperature range of −20° to +180°F, and has high resistance to the ravages of weather, moisture, ozone and chemicals. It maintains an effective bond between practically all building materials, with similar and dissimilar substrates, surface textures and expansion rates, including metals, masonry, glass and wood.

*Registered trademark of the Thiokol Chemical Corporation

ADVANTAGES

- Excellent for all joints having movement due to temperature changes.
- Cures to a flexible, rubbery, non-sagging, non-staining seal which will not harden, crack, or lose adhesion upon aging.
- Maintains an effective bond between practically all building materials, with similar or dissimilar substrates, surface textures and expansion rates.
- Withstands extremes of repeated joint expansion/contraction over a wide temperature range.
- Has high resistance to ravages of weather, moisture, ozone and chemicals.

APPLICATION

Joint Dimensions: CM-60 Sealant is designed for use in joints having a minimum width of 1/4". Performance of the sealant is dependent upon joint design; joint width should be a minimum of four times the anticipated joint movement between temperature extremes.

Sealant Depth: For optimum sealant performance, the joint sealant shape should be controlled to provide 1/4" depth minimum for joint widths up to 1/2"; for joints between 1/2" and 1", the sealant depth should be 1/2 the joint width; for joints over 1" wide, sealant depth may be maintained at 1/2". Control sealant depth by inserting SEALTIGHT Backer Rod, which also acts as a bond breaker preventing three point adhesion, i.e., adhesion at the bottom of the joint.

Joint Preparation: Joint surfaces must be clean, dry and free of all contaminants, such as curing compounds, form release agents, protective coatings and oil, grease or bitumens, all of which will interfere with the adhesion of the sealant.

For New Concrete: Remove all loose material by wire brushing. Surfaces exposed to form release agents and curing compounds should be cleaned by sandblasting or equivalent abrading. Laitance removed by abrading. Fresh concrete must be fully cured.

For Old Concrete: All old joint sealing materials must be removed by mechanical means. Joint faces containing absorbed oils or bitumens must be cut back to clean, sound concrete.

Metal Surfaces: All protective coatings must be removed by cleaning and wiping with Methyl Ethyl Ketone or Xylol; final wipe with clean cloth and fresh solvent.

Glass Surfaces: Remove oil and dirt films by solvent wiping, using clean cloth and fresh solvent.

W. R. MEADOWS, INC.
P.O. BOX 543 • ELGIN, IL 60120
Other Plants
HAMPSHIRE, IL / ATLANTA, GA / YORK, PA
FORT WORTH, TX / BENICIA, CA / WESTON, ONT

OhioEPA
State of Ohio Environmental Protection Agency
Northeast District Office

2110 E. Aurora Road
Twinsburg, Ohio 44087-1969

TELE (330) 425-9171 FAX (330) 487-0769

Bob Taft, Governor
Christopher Jones, Director

August 21, 2000

RECEIVED
AUG 25 2000
MNOHWI PERMIT SECTION - WMB
Waste, Pesticides & Toxics Division
U.S. EPA - REGION 5

Mr. Mike Mraz
Hukill Chemical Corporation
7013 Krick Road
Bedford, OH 44146-4493

Re: ***Hazardous Waste Permit Modification, Class 1A Notice of Deficiency***
Hukill Chemical Corporation, U.S. EPA ID: OHD 001926740
Ohio EPA ID: 02-18-0315, Installation of the Auger, Cuyahoga County

Dear Mr. Mraz:

On July 26, 2000, Ohio EPA received a request for a Class 1A permit modification (PITS # 000801-1A-1) from Hukill Chemical Corporation (Hukill).

The Ohio EPA, Division of Hazardous Waste Management (DHWM) has conducted a completeness/technical adequacy review of the above referenced modification application, and has determined it to be incomplete and technically inadequate. This application has been reviewed pursuant to the rules published in the Hazardous Waste Facility Standards Chapters in the Ohio Administrative Code ("OAC") and the corresponding Federal regulations.

We have enclosed completeness/technical adequacy comments that are the result of this review as Attachment 1. Please provide detailed information addressing all areas indicated on the comment sheets to Ohio EPA within 15 days of the date of receipt of this correspondence. This submission shall be in accordance with the following editorial protocol or convention:

EDITORIAL PROTOCOL

1. Old language is overstruck. Delete language overstruck in previous versions as necessary to maintain only current language and its immediate antecedent overstruck language.

2. New language is capitalized.

3. Page headers should indicate date of submission or version designation.

4. If significant changes are necessary, pages should be renumbered, table of contents revised, and complete sections provided as required.

5. Each original application, or amended version must be prefaced by an updated "List of Effective Pages." The purpose of this requirement is to create a standard mechanism to specify and verify the content of the Part B permit application. Each "List of Effective Pages" must contain, at minimum, an inventory of pages for the entire document, posting directions, and a chronology of versions. The inventory of pages must positively identify each effective attachment by its page, drawing, figure, or table designation, and, unless an original page, by its current version designation or date of submission as specified in the inventory of pages. Attached are two examples of "List of Effective Pages" and associated page markings. RCRA Engineering Section, Division of Hazardous Waste Management, Central Office, Ohio EPA may authorize individual facilities to use an alternate method of specifying the content of their Part B permit application on a case-by-case basis.

6. Each original application, or version must be accompanied by a certification letter as specified in OAC Rule 3745-50-42(D).

Please send one copy each to:

Tom Crepeau, Manager
Ohio EPA, DHWM
Data Management Section
122 S. Front Street
P.O. Box 1049
Columbus, Ohio 43216-1049

Harriet Croke, Chief
Ohio Permitting Section (HRP-8J)
Waste Management Division
U.S. EPA, Region 5
77 West Jackson Boulevard
Chicago, Illinois 60604

Please send two copies to:

Joe Loucek, Environmental Specialist
Ohio EPA, Northeast District Office
2110 East Aurora Road
Twinsburg, Ohio 44087

In the course of the technical adequacy review, we may request additional information if it is necessary to clarify, modify, or supplement previous submissions of information in order to substantively evaluate the permit application for adequacy.

Failure to submit a complete permit application or to correct deficiencies in the application may result in the following:

1) Revocation of your existing Ohio Hazardous Waste Facility Installation and Operation

2) Denial of the permit application; and

3) Referral of the matter to the Ohio Attorney General's Office for appropriate enforcement action.

If necessary, Hukill may contact Joe Loucek of the Northeast District Office at (330) 963-1258 within ten (10) days of receipt of this NOD to discuss each of the enclosed comments in order to make clear the information being requested. This can be accomplished by a conference call or meeting.

Thereafter, any questions concerning the review of this permit application and the level of detail expected should also be addressed to Joe Loucek.

Sincerely,

Joseph C. Loucek, III
Environmental Specialist
Division of Hazardous Waste Management

JCL:ddw

cc: Harriet Croke, Region V, USEPA
Jeremy Carroll, EU, DHWM, CO
Tom Crepeau, DMS, DHWM, CO
Pam Allen, CAS, DHWM, CO
Joe Loucek, DHWM, NEDO
Frank Popotnik, DHWM, NEDO
Mike Joseph, DHWM, CO

ATTACHMENT 1 - Comments on the Class 1A Modification Request for Hukill Chemical Corporation to Install an Auger System

General Comments:

1 Red text is not acceptable. The red text is useful for a working copy and from an editorial standpoint is appreciated. However, the red text does not carry through onto additional copies Ohio EPA may need to make of the updated pages. The set protocol is as follows:

The Revised Class 1A modification shall be prepared in accordance with the following editorial protocol or convention:

a. Old language is overstruck. Delete language overstruck in previous versions as necessary to maintain only current language and its immediate antecedent overstruck language.

b. New language is capitalized.

c. Page headers should indicate date of submission or version designation.

d. If significant changes are necessary, pages should be renumbered, table of contents revised, and complete sections provided as required.

e. Each original application, or amended version must be prefaced by an updated "List of Effective Pages." The purpose of this requirement is to create a standard mechanism to specify and verify the content of the Part B permit application. Each "List of Effective Pages" must contain, at minimum, an inventory of pages for the entire document, posting directions, and a chronology of versions. The inventory of pages must positively identify each effective attachment by its page, drawing, figure, or table designation, and, unless an original page, by its current version designation or date of submission as specified in the inventory of pages. Attached are two examples of "List of Effective Pages" and associated page markings. RCRA Engineering Section, Division of Hazardous Waste Management, Central Office, Ohio EPA may authorize individual facilities to use an alternate method of specifying the content of their Part B permit application on a case-by-case basis.

2 The pages should be revised to remove previously approved comments. It is confusing and inappropriate to not submit a clean copy showing only current proposed changes.

3 Only submit those pages that are directly affected by this current permit modification.

4 Hukill should resubmit the auger class modification determination request information as part of this class 1A modification request.

Section D Permit Modifications:

5 Page 11 The section entitled, Tanks Storing Hazardous Waste, sixth paragraph, second line reads "*...considered a permitted hazardous waste storage tank.*" Until the ORC section 3734.0(2)(G) exemption is approved, the auger system will treat exempt waste (waste sent to BIFs) only. It is premature and inappropriate to consider this section a "permitted hazardous waste storage tank".

6 Page 22 The section entitled, Auger System Tank (750 gallon), refers Figure 1 in Exhibit D-12. It is acceptable to submit a reduced size drawing, as found in the submitted permit modification request. However, if you do this, the reduced-size drawing must be modified from the original in that all text is readable. Please revise Figure 1, making all text readable. Drawing details specific to the auger should also be clearly visible on the drawing.

7 Page 22 The section entitled, Design, paragraph 1, first sentence reads "*...haz.waste fuel blends.*" Again, use exempt language when referring to treating hazardous waste within the auger. This language would be appropriate in the ORC section 3734.0(2)(G) exemption request, but not here.

8 Page 22 The section entitled, Design, paragraph 2 describes the normal flow of materials through the fuel blending operation. A figure should be included that matches exactly the descriptions used in the body of this section text of the layout and operation of the auger system. This may be the purpose of Figure 1, but in its current font size, this is indeterminable.

9 Page 23 Third paragraph, last line reads "*...removed for reconditioning or disposal.*" Additional information should be included as to any cleaning procedure which may be followed. If it is anticipated that after the auger, the drums will be RCRA empty, such a comment should be provided. Since the auger is original equipment manufactured (OEM) equipment, a contingency should be included in the event the drums are not RCRA empty after the auger.

10 Page 23 The section entitled, Management, second line reads "*...will be cleaned periodically.*" Periodically must be defined (e.g., weekly, monthly) and why this interval is chosen. Please note, "as needed" is not an appropriate way to define periodically, nor is it a suitable substitute.

11	Page 23	The section entitled, <u>Inspections</u>, second sentence reads "*The containment is the same...*" Some reference should be made to where the steel floor is already described within the permit.
12	Page 23	The section entitled, <u>Inspections</u>, second sentence also reads "*...will be inspected (along with the tank)...*" Therefore, the inspection log needs to be updated and included as a page change with this modification request.
13	Page 24	The section entitled, <u>Requirements for Ignitable or Reactive Wastes</u>, first paragraph again refers to "hazardous waste" stored in the auger system tank. The language should be revised to state it will only manage exempt waste (waste sent to BIFs).
14	Page 24	Space is needed between first and second paragraph. A period is needed at the end of the second sentence.
15	Page 24	The section entitled, <u>Requirements for Ignitable or Reactive Wastes</u>, second paragraph, first line reads "*...is a restricted area.*" This is already described in detail within the permit. The appropriate sections of the approved permit should be referenced here.

<u>Section F Permit Modifications:</u>

16	Page 10	Comparing page 10 of the permit (section F-4a(2) - Unload To Recovery) to the proposed changes, the pages do not "match". Page 10 of this submittal should start with "*Container Building. As detailed in Section D...*" as it does on the existing page 10 (from the permit).
17	Page 10	Second full paragraph, line four discusses use of a drip pan under the conveyor. Please provide detail on the drip pan, including, but not limited to material of construction, size, etc. The extent to which the drip pan provides overspill collection should also be shown on the figures.
18	Page 13	First full paragraph, third line reads "*...handling equipment will be reviewed...*" The fourth line reads "*Heat sensors will be integrated...*" A time line for these activities and final report documenting the final installation should be submitted to Ohio EPA. The paragraph should be revised to reflect this addition.

Part B Permit Modifications:

19	Page 27	"insert Exhibit A" should all be capitalized.
20	Exhibit A	The entire paragraph should all be capitalized.
21	Exhibit A	Fourth line reads "*...tank contents is pumped...*" Detail as to specifically where the contents are pumped, and how they get there should be included here.

Exhibit D-12 Comments:

22	Introduction	Second paragraph, first line reads "*...plans to installed...*" "*installed*" is a typo and should be corrected.
23	Introduction	In the second paragraph, the auger system is referred to as "*Auger System*". In the third paragraph it is referred to as the "*Auger/Pulper System*". Since neither term is defined, either define both, pointing out the differences, or settle on one term.
24	Introduction	Third paragraph, first line reads "*...within the containment area...*" That should be revised to make it clear the containment already exists.
25	Introduction	Third paragraph, third line refers to Figure 1 on the following page. Please see comment number 6 above.
26	Introduction	In the fourth paragraph, Hukill should make it clear that the steel containment is existing.
27	Page 7	<u>Auger System Tank</u>, section 1, first paragraph, first line reads "*...will be equipped...*" Details as to when the fire suppression system will be installed should be included. Detail should be included as to whether or not this system needs to be installed/certified by a professional, and the supporting rationale for that decision.
28	Page 7	<u>Auger System Tank</u>, section 1, first paragraph ends with "*fire water storage tank*". The second paragraph begins with "*Tank filling*". Obvious from the text of the second paragraph the discussions are of two different tanks. This needs to be made clearer.

29	Page 7	Auger System Tank, section 1, second paragraph fourth line reads "*...and taking appropriate action.*" Appropriate action should be defined.
30	Page 7	Ancillary Equipment, section 2 - this section should be revised to provide detail demonstrating the purpose of the pulper, including detail as to why it is considered ancillary and not intrinsic to the design of the auger system.
31	Page 7	Secondary Containment, section 3 discusses Figure 1. Please see comment number 6 above.
32	Page 7	Secondary Containment, section 3 also discuss the existing steel liner. Verbiage should be added that makes it clear the liner is already in place. In light of the first paragraph on page 8, this is important as this will eliminate any questions regarding precedence.
33	Page 8	First paragraph reads "750 gallons..." "*...is the minimum required containment...*" This seems inconsistent when compared to section 3.b which states the 750 gallons "exceeds the minimum containment." Both statements should be further clarified.
34	Page 8	Third paragraph reads "*The containment **is** inspected daily and spills **would be**...*" Since the inspections already occur, would it not be more appropriate to state that spills *are* removed within 24 hours? This paragraph also mentions the daily inspection of the containment area. Please see comment number 11 above.
35	Page 8	Section 3.b, second line reads "*...since these tanks...*" This document is for describing the auger tank and system in light of the permit modification request. It is not appropriate to discuss plural tanks. This paragraph should be revised in light of comments made above regarding the first paragraph on this page. You may include reference to the other tanks within the containment area, so long as specific singular reference is made to the auger tank system, and its impact on containment capacity.
36	Page 9	Corrosion Protection Measures, first paragraph reads "*...HHC has maintained a protective coat...*" To Ohio EPA's knowledge, no maintenance has occurred on the auger tank to date justifying this statement.

37	Page 9	Corrosion Protection Measures, first paragraph, second line reads "*As stated in the...*" there needs to be the appropriate reference to that section of the Waste Analysis Plan (WAP).
38	Page 9	Corrosion Protection Measures, first paragraph, third line reads "*...hazardous waste destined for this tank system...*" to which tank system does this line refer, and what is the significance of this statement in light of a discussion on the auger tank system? Further, since this is in reference to the auger tank, references to it storing hazardous waste should be removed.
39	Page 9	Corrosion Protection Measures, first paragraph, last line reads "*...prior to or during transfer to the storage tank.*" To which storage tank does this line refer, and what is the significance with regard to the auger system?
40	Page 9	Corrosion Protection Measures, second paragraph starts with "*This tank*" and ends with "*...this system.*" This paragraph should be revised to maintain uniformity of descriptions throughout.
41	Page 10	Third and Fourth paragraphs, last line in each paragraph reads "*...or when pinhole leaks begin appearing...*" Those sentences need to end with "*whichever happens first.*"
42	Page 10	Fifth paragraph states that a of a factor of 2 is used to increase the minimum plate thickness, as described in the second and third paragraphs (The 2 is representative of some factor of safety). How was this value determined from a feasibility, engineering, and regulatory standpoint? What is the justification for its use versus, say a value of 3.5?
43	Page 10	Section 1.a - Seismic Considerations - second paragraph, what is the significance of the factor of safety for seismic forces?
44	Page 10	Section 1.c - Frost Heave - in both 1.a and 1.b, a simple definition for the load is provided according to the OBBC guidelines. It is inappropriate to remove the definition from 1.a. In order to have uniformity and consistency in the document presentation, a like definition should be provided for frost heave.

45	Page 11	Section 2.a - Full Tank - Hukill should explain why the 1.33 value is used. Please provide a reference. Where are the calculations for the load on one leg? Hukill should explain why the soil bearing capacity is used. The terms were switched from "*soil capacity*" to "*concrete slab floor*". Please change verbiage such that the document maintains consistent use of terminology. If the soil bearing capacity comes from the strength of the concrete and underlying bedding, engineering drawings from the installation of the concrete should be provided, or referenced if already part of the facility's hazardous waste permit.
46	Page 11	Section 3 - Secondary Containment, second line reads "*The fact that ... has been described as non-critical.*" Where has this been done? Please cite the references where this fact has been determined to be non-critical, being sure the term "*non-critical*" is used and defined within the reference citation.
47	Page 13	Section 2 - Non-Destructive Testing - what is the precedent for Hukill testing the tank thickness annually where other tanks at the facility are tested semi-annually? This section should follow Part B Permit Condition D.5(d), and permit should be modified to include this item as D.5(e). The current D.5(e) should become D.5(f). If it decided the tank thickness test will be performed semi-annually, permit condition D.5(d) should be modified to include the auger tank.
48	Page 13	Section 4 - Ancillary Equipment - this section fails to list the pulper as a piece of ancillary equipment as in Section 2, page 7 of this document. Further, that same section does not list the drum auger, pipes, valve, and fittings as ancillary equipment. This discrepancy must be addressed.
49	Page 13	Section 5 - Installation Certification - According to the previous page (*Certification Statement for Written Assessment for the Design of the Tank System*), the auger system is already installed. As such, the first paragraph of this section should be dated.
50	Page 13	Section 5 - Installation Certification - for clarity, third paragraph should state why "*the placement, backfilling and corrosion due to soil/water contact is not applicable to this installation.*"
51	Page 15	The *Certification Statement for the Installation of the Tank System* has not been signed/stamped.

Calculations:

52	Page 1	Hukill should explain from where the 1.33 (maximum use) is used for the specific gravity.
53	Page 1	In the 2" x 2" angle rim weight calculation, Hukill should why 3.19 is used.
54	Page 1	In the shell weight calculations, Hukill should explain why 10.2 and 20.4 lb/sqft is used.
55	Page 2	In the bottom plate weight calculation, Hukill should explain why 20.8 is used. Hukill should explain why 1/4" is used.
56	Page 2	In the baffle weight calculation, Hukill should explain why 6.6 is used.
57	Page 2	Why is the 4x4 used in the leg weight calculation but not the baffle weight calculation? From the Auger System Tank figure, it would seem to me the calculations would be similar as the pieces appear similar.
58	Page 2	In the legs, weight calculation, Hukill should explain why 8.2 is used. Hukill should explain why 5/16 is used.
59	Page 2	According to the figure, it appears as though the legs have plates welded to the bottom of each leg. The calculation for the weight of these plates, could not be found in the submittal.
60	Page 2	Hukill should explain why weights for the agitator support framing, shaft, arms and pulley, motor, and misc. appurtenances is used.
61	Page 2	In the weight of liquid in the upper shell calculations, Hukill should explain why 62.4 is used.
62	Page 2	Hukill should explain why volume below the upper shell value is used.
63	Page 2	In the weight of liquid below the upper shell calculations, Hukill should explain why 62.4 is used.
64	Page 3	In the tank legs calculation, Hukill should explain why 1.94 sq in is used. Hukill should explain why radius of gyration is used.

65	Page 3	In the load on one leg calculations, Hukill should explain why 800/2 is used. Where did this equation is used.
66	Page 3	The calculations in 4. Check Tank Legs should follow the format the engineer used in 5A.
67	Page 3	The calculations in 5A - Calculation of Required Tank Wall Thickness – Cylindrical Shell, how was an f of 12,600 psi determined? What does the [2.1] reference? There is no equation called 2.1 within this document.
68	Page 3	The calculations in 5A - If there is going to be a nominal thickness term used, it must be defined or given a value in this document. The obvious place is under the unit description on page 1 of the calculations.
69	Page 3	The calculations in 5A - Where is service factor(SF) defined? How, looking at an SF of 24.0 does one recognize/know that the cylindrical shell is "*OK*"? Include a reference to the service factor discussion and include a 24.0 > 2.0 (from the textual discussion of service factor) line within this calculation, to include a brief verbal discussion here.
70	Page 4	The calculations in 5B - Longitudinal Force - uses the term "*Spring Line*". The diagram marked Appendix A (same as Figure 2) is supposedly the reference diagram for the calculations. It needs to be marked with the Spring Line.
71	Page 4	The calculations in 5B - Longitudinal Force - there is no "*hc*" in the calculation, so why is it defined with the other terms?
72	Page 4	The calculations in 5B - Longitudinal Force - in the calculation to determine θ, where is the 15" used? It should be defined, or shown graphically with a sketch (the sketch can be in the margin on that page).
73	Page 4	The calculations in 5B - Hoop Force - What is the significance of "*2,793 lb/ft > 1,490 lb/ft*"?
74	Page 4	The calculations in 5B - Hoop Force - how was an "*f*" of 12,600 psi determined? What does the [2.1] reference? There is no equation called 2.1 within this document.

75	Page 5	The calculations in 5B - If there is going to be a nominal thickness term used, it must be defined or given a value in this document. The obvious place is under the unit description on page 1 of the calculations.
76	Page 5	The calculations in 5B - Where is service factor(SF) defined? How, looking at an SF of 24.0 does one recognize/know that the cylindrical shell is "*OK*"? Include a reference to the service factor discussion and include a 24.0 > 2.0 (from the textual discussion of service factor) line within this calculation, to include a brief verbal discussion here.
77	Page 5	In calculating the maximum effective area of compression, the calculation states to use 1.068 as the value instead of 2.0. That decision needs to be explained. A small table below the service factor calculation on page 6 showing use of 2.0 to be more restrictive is sufficient (with reference to it on page 5).
78	Page 5	In the Summation of Forces calculation, include references.
79	Page 6	What is the significance of "*12,037 psi < 15,000 psi*"?
80	Page 7	Under 8. Foundation Investigation, what is the source of the 2'-0"? Why is 2'0" used?
81	Page 7	Under 8. Foundation Investigation, from where does 4,000 psf load bearing capacity for the slab and soil come? Ohio EPA requires some sort of proof (drawings, etc.) of such values. If the drawing has previously been submitted and is part of the permit, it can be included by reference.
82	Page 7	Under 8. Foundation Investigation, from where does the 3,765 lbs come? That needs to be included.
83	Page 7	Under 9. Containment Curb, what is being called the containment curb? Figure 3 should be referenced, as it is marked on there, though not clearly readable.
84	Page 8	Please use proper bibliographic reference format. Attachment 2 is an example of how reference lists should be formatted.

85	Appendix 1	The language in the first paragraph on this page, where it reads "*...in the permitted container storage area.*" is exemplary verbiage where I ask that it is made clear that the steel secondary containment is already permitted/existing (other comments on this list).
86	Appendix 1	The third paragraph, first line reads "*...by 4 ½ inch deep...*" This should be revised to read "...by *4 ½ inch (0.375 feet) deep...*" Doing so eliminates confusion in the gross volume calculation of where the 0.375' value comes from.
87	Appendix 1	The third paragraph, first line reads "*...of the dike...*" This is the first mention of a dike. This statement should be reworded to maintain consistency throughout the discussion.
88	Appendix 1	The sixth paragraph, second line reads "*...7.481 gal/ cu ft...*" Where does this value is used, and how does it relate to the 1.33 maximum specific gravity used throughout the body of Exhibit D-12? Any conversion from specific gravity to gal/cu ft should be shown.
89	Appendix 1	The seventh paragraph, first line describes an aisle space within the secondary containment. Please provide, at a minimum a sketch representing these dimensions. As written, there is room at the bottom of the page for the graphical representation.
90	Appendix 1	The seventh paragraph, fifth line reads "*...4 ½ inches, (0.375 ft.)...*" This should be revised to read "*...4 ½ inches (0.375 ft.),...*" The comma is misplaced.
91	Appendix 1	It is unclear which way the ramp raises. Please provide detail as to whether the ramp raises up into the steel secondary containment area, or if the ramp drops down into the steel secondary containment area.

ATTACHMENT 2 - Select References for Exemplary Purposes

References

(1) Gilbert, R. O., 1987. *Statistical Methods for Environmental Pollution Monitoring*, Van Nostrand Reinhold, New York.

(2) Hayes, W.B., and G. S. Koch, 1984. *Constructing and Analyzing Area-Of-Influence Polygons by Computer,* Computers and Geosciences Vol. 10, No. 4, pp. 411-430.

(3) Lukovic, D., 2000. *Sampling Grid Calculator*, Ohio Environmental Protection Agency, Division of Hazardous Waste Management, Columbus, Ohio.

(4) Ohio Environmental Protection Agency, 1999. *Closure Plan Review Guidance*, Division of Hazardous Waste Management, Columbus, Ohio.

(5) Schweitzer, G. E., and J. A. Santolucito (editors), 1984. *Environmental Sampling for Hazardous Wastes*, ACS Symposium Series No. 267, American Chemical Society, Washington, D.C.

(6) U.S. Environmental Protection Agency, 1984. *Characterization of Hazardous Waste Sites: Methods Manual*, Volumes 1 and 2, Office of Research and Development, U.S. Environmental Protection Agency, Las Vegas, Nevada.

(7) U.S. Environmental Protection Agency, 1996. *Soil Screening Guidance: Technical Background Document*, Office of Emergency and Remedial Response, U.S. Environmental Protection Agency, Washington, D.C.

HUKILL CHEMICAL CORPORATION

7013 KRICK ROAD • BEDFORD, OHIO 44146-4493 • 440 / 232-9400 • FAX 440 / 232-9477

Over Fifty Years of Quality Products and Services

March 2, 2000

CERTIFIED MAIL

Ms. Harriet Croke
RCRA Permitting Branch
HRP-8J
77 West Jackson Blvd
Chicago, IL 60604

OHD 001 926 740

Dear Ms. Croke:

In accordance with OAC 3745-50-51(C)(1)(a)(ii), this letter shall serve as your notification that Hukill Chemical Corporation, a permitted Part B facility, has implemented one (1) Class 1A and three (3) Class 1 permit modifications. Class 1 modifications are administrative or informational changes. Class 1A modifications require prior approval of the Director of the Ohio EPA.

- Class 1A Modification (dated December 10, 1999) requesting a one-year extension to the Spent Acid tank closure deadline to account for remediation of underlying contaminated soils.
  Assigned OEPA tracking number 991220-1A-01 and approved January 6, 2000.

class 2 mod. ?

- Class 1 Modification (dated December 8, 1999) replacing one 21,000-gallon tank with two 14,000-gallon tanks.
  Assigned OEPA tracking number 991213-1A-01 and approved by OEPA January 7, 1999.

- Class 1 Modification (dated November 30, 1999) requesting six informational changes to Section D – Process Information.

  Assigned OEPA tracking number 991202-1-01 through 991202-1-06 and approved January 24, 2000.

- Class 1 Modification (dated January 30, 2000) changing the reporting schedule for progress reports from monthly to quarterly to conform with Agency guidance.

  Assigned OEPA Tracking number 000131-1-01 and approved February 16, 2000.

If you have any questions or concerns about these modifications, please contact me at the number listed above.

Respectfully,

Judy Trader

Judy Trader
Environmental, Health & Safety Engineer

Cc: Marlene Kinney, Ohio EPA - DHWM

RECEIVED
APR 10 2000
RCRA RECORDS ROOM
Waste, Pesticides & Toxics Division
U.S. EPA – REGION 5

HUKILL CHEMICAL CORPORATION

7013 KRICK ROAD • BEDFORD, OHIO 44146-4493 • 440 / 232-9400 • FAX 440 / 232-9477

Over Fifty Years of Quality Products and Services

August 19, 1999

Ms. Harriet Croke
RCRA Permitting Branch
HRP-8J
77 West Jackson Boulevard
Chicago, IL 60604

Re: Hukill Chemical Corporation
US EPA I.D. Number OHD001926740
May 21, 1999 Class1/1A Modification Requests

Dear Ms. Croke,

In accordance with OAC 3745-50-51 (c)(1)(a)(ii), this letter shall serve as your notification that Hukill Chemical Corporation has submitted two Class 1 modification requests and two Class 1A modification requests to the Ohio EPA. Class 1 modifications are administrative or informational changes that can be implemented right away without Ohio EPA approval. Class 1A requests require the OEPA Director's approval prior to implementation. The following details the modifications and Ohio EPA's response to the four modifications:

- **Class 1:** The update to Section I of the Part B permit application includes the most recent closure/post closure cost estimate. This administrative change was acknowledged by OEPA in a letter dated June 9, 1999 and was assigned a tracking system (PITS) ID number of 990525-1-1.
- **Class 1:** The second update to Section I of the Part B permit application, to change Table 3 and Table 3A to reflect the current rinseate standards, was assigned a PITS ID number of 990525-1-2. This was acknowledged by OEPA in a letter dated June 9, 1999.
- **Class 1A:** Modification of the timeframe found in permit condition A.26(b)(iii), submittal of an approvable closure plan. This was approved by OEPA in a letter dated June 9, 1999 and was assigned a tracking system PITS ID number of 990525-1A-1.
- **Class 1A:** Change in the closure schedule to extend the closure period for closure of the spent acid tank from 180 days to 270 days. This was approved by OEPA in a letter dated June 10, 1999 and was assigned a tracking system PITS ID number of 990528-1A-1.

If you have any questions, please feel free to contact me at the number listed above or you can contact Ms. Marlene Kinney with OEPA at (330) 963-1162.

Respectfully,

Jennifer P. Zylko
Environmental, Health and Safety Manager
Hukill Chemical Corporation

HUKILL CHEMICAL CORPORATION

7013 KRICK ROAD • BEDFORD, OHIO 44146-4493 • 440 / 232-9400 • FAX 440 / 232-9477

Over Fifty Years of Quality Products and Services

March 5, 1999

Ms. Harriet Croke
RCRA Permitting Branch
HRP-8J
77 West Jackson Boulevard
Chicago, IL 60604

Re: Hukill Chemical Corporation
U.S. EPA I.D. Number: OHD001926740
Ohio EPA I.D. Number: 02-18-0315
Class 1-A Modification Request Approved and Implemented

Dear Ms. Croke,

In accordance with OAC 3745-50-51(C)(1)(a)(ii), this letter shall serve as your notification that Hukill Chemical Corporation, a permitted 'Part B' facility, has implemented a Class 1A modification which was approved by the Ohio EPA on January 20, 1999. Class 1A modifications are administrative or informational changes that require approval before implementation.

This modification made changes to an interim compliance date as agreed to in a meeting with the Northeast District Office (NEDO) of the Ohio EPA in December 1998. The compliance date was replaced with a requirement for monthly progress reports. This change allows for better, ongoing communication with the agency, and will help ensure that the final submittal will be acceptable to the agency. The first monthly progress report was submitted to the NEDO on February 2, 1999.

If you have any questions on this matter, please feel free to contact me at the number listed above.

Respectfully,

Jennifer P. Zylko

Jennifer P. Zylko
Environmental, Health and Safety Manager
Hukill Chemical Corporation

cc: Marlene Kinney - Ohio EPA, NEDO